4.0 PRELIMINARY MANAGEMENT ALTERNATIVES

This section describes flow management and non-flow alternatives evaluated in the course of developing the LMRMP. Alternatives are described by hydrologic reach, moving downstream from Pardee Reservoir.

4.1 PARDEE TO CAMANCHE REACH

Several of the management alternatives proposed for the Lower Mokelumne River include flow strategies in the reach between Pardee Dam and Camanche Reservoir. These flow recommendations are based on maintaining water quality suitable for chinook salmon and steelhead trout in the river below Camanche Dam. The reach between Pardee and Camanche reservoirs cannot be managed separately from the lower river because this reach is the conduit through which the operation of the two reservoirs is synchronized to meet flood control requirements, irrigation demands, municipal water supply needs, and flow requirements for the lower river's riparian and aquatic communities. Flow requirements in this reach may compromise downstream water quality management.

If flows were stabilized in this reach of the river, it is unlikely that a self-sustaining fishery of recreational importance would develop. Given the elevation of Camanche Reservoir, more than 80 percent of the area in this reach consists of pool habitat; riffles comprise less than 10 percent of the total habitat area (Appendix A). Furthermore, most of the substrate in all habitat types, including riffles, consists of fines. The high percentage of fines, bedrock, and large cobble in riffle and run habitat severely limits spawning habitat for salmonids in this reach. In 1991, trout density (fish/100 m^2) in this reach was less than 1.2 in riffles and less than 2.8 in runs (Appendix A). At higher flows, the confined stream channel creates a deep, high velocity run with almost no spawning habitat.

Another problem preventing development of a self-sustaining fishery is that this running water reach is entirely eliminated when Camanche Reservoir is full (elevation 71.8 m), as water from Camanche Reservoir backs up to the base of Pardee Dam. Fish typical of the reservoir move into the reach and prey upon and compete with stream fishes, reducing their numbers. Many of the stream fish also disperse into the main body of the reservoir, further reducing their local abundance. Once the reservoir water recedes, fish abundance in this reach is probably substantially reduced. Furthermore, safe access is not available.

The best management strategy for this short reach between the reservoirs is to maintain a flow of at least 3 cfs to protect the in-river fishery, and allow substantial operational flexibility to maintain high water quality in the lower river for chinook salmon and steelhead trout.

4.2 CAMANCHE RESERVOIR

During the recent years of drought, the water level in the reservoir has been lower than normal and water for the Lower Mokelumne River and the MRFH has come solely from the lower (31 m) of the two outlets (62 m and 31 m) in Camanche Reservoir. This low elevation reservoir is broad and shallow and algal productivity is unusually high. The reservoir is typical of a eutrophic lake; it stratifies during the summer creating a warm surface layer prone to blue-green algal blooms and a cold deep and anoxic bottom layer. The reservoir behaves like two separate reservoirs — a smaller, shallow and narrow reservoir at the upper reach and a large, broad, and deeper body of water near Camanche Dam.

The primary water quality parameters associated with fish losses are warm water (related to premature destratification of the reservoir), low levels or absence of dissolved oxygen in the hypolimnion, and toxic concentrations of hydrogen sulfide generated under anoxic conditions in the hypolimnion. EBMUD has identified and evaluated several water quality improvement alternatives over the past several years. The following sections describe and evaluate each improvement alternative and the alternative selected.

4.2.1 Operational Strategies

The intent of the proposed operational strategy is to provide sufficient flows and water quality to meet EBMUD's LMRMP, while providing EBMUD with an adequate and reliable water supply. In addition to these goals, the strategy provides flexibility in day-to-day implementation. This will allow new information and actual field observations to be integrated into the strategy to achieve the goals of the LMRMP. As discussed in earlier sections, the effect of management practices on fish populations cannot always be predicted with accuracy because of a lack of information. Other uncertainties, including variable hydrologic conditions, uncertain future water demands, and the limited water quality and operating system data base currently available, further reinforce the need to plan for maximum flexibility to permit future refinement and optimization.

In the following sections, flows are presented for the Lower Mokelumne River for different hydrologic years to provide suitable escapement, spawning, rearing, and emigration conditions for fall-run salmon, as well as suitable summer habitat for steelhead trout and other resident species. Water temperatures required in the river under those flow conditions were also determined. Alternative strategies were evaluated based on their ability to meet these flow and water temperature requirements for the historical period from 1921 through 1991. To evaluate the performance of alternatives in the design drought, the hydrological data for the year 1978 were substituted with a hypothetical 185 TAF runoff year in the third year of the design drought.

The two alternative operational strategies identified and evaluated are the CDFG Plan suggested by the CDFG and the LMRMP developed by EBMUD and BioSystems.

4.2.1.1 CDFG Plan

Rationale - CDFG has proposed an interim minimum storage elevation of 64 meters in Camanche Reservoir and a continuous inflow from Pardee Reservoir of 250 cfs, pending results of further reservoir operations studies (CDFG 1991). The scientific basis for developing these recommendations is not identified in their report.

Evaluation - CDFG has not scientifically established the need for these operating criteria, particularly in light of the successful operation of the MRFH in recent years, during which Camanche Reservoir has been at substantially lower levels (55 meters). Using the EBMUDSIM computer model, EBMUD evaluated the effects of the CDFG Plan on the operation and storage capacity of the Camanche/Pardee Reservoir system. During the design critical drought, this alternative would result in a shortfall (or Need for Water) of 720 TAF for the simulated year 2020 condition. In 28 years out of the 70 years evaluated, Pardee Reservoir would be drawn down to a minimum pool, EBMUD would have to obtain alternative water supplies, and downstream water quality and quantity may be substantially impaired. (This subject is treated in more detail in Section 5.0).

4.2.1.2 LMRMP (Preferred Alternative)

Rationale - This alternative is intended to keep Camanche release temperatures cool enough to meet the temperature criterion of the LMRMP by maintaining stratification in Camanche Reservoir. To do this, a minimum volume would be maintained in the hypolimnion of Camanche Reservoir through the summer and fall. Frequent and intensive monitoring of the stratification condition and water quality of Pardee and Camanche reservoirs that is currently conducted would be continued to provide a growing scientific data base upon which operational decisions would be made. Release of cool water from the hypolimnion of Pardee Reservoir could be used to replenish and maintain a hypolimnion in Camanche Reservoir, preserving stratification from April to November. Pardee Reservoir would be operated to eliminate premature destratification of Camanche Reservoir during this time, as premature destratification would cause Camanche release water to be too warm for fish in the Lower Mokelumne River.

For the LMRMP to be effective, Pardee Reservoir would also have to remain stratified so that a cool water supply would be available for release from Pardee to maintain stratification in Camanche. An estimated minimum storage volume of 100 TAF in Pardee Reservoir is believed necessary to maintain stratification (Alex. Horne, pers. comm. 1992). The release of Pardee water to Camanche Reservoir would continue as needed as long as the projected water storage in Pardee at the end of October was above 100 TAF. Below this level Pardee Reservoir could destratify, making the release water too warm to be effective in controlling stratification in Camanche Reservoir. Pardee Reservoir would be monitored to accurately measure the volume of cool water available for release to Camanche to meet the LMRMP objectives.

__Evaluation__ - Development of this alternative was based on EBMUD's operational experience in 1990 and 1991 (Horne 1992). When Camanche and Pardee reservoirs were operated to maintain cool water releases to the MRFH and the river. The water levels in Camanche Reservoir in 1990 and 1991 were similar to those in 1987 when warm water from early destratification caused a fish kill in the MRFH. Data from the last two years show that the hypolimnion in Camanche could be replenished and maintained by cold water releases from Pardee Reservoir. Maintenance of a hypolimnion in Camanche enables it to remain stratified until November when the reservoir and river cool naturally.

Computer studies (WQRRS) simulating this alternative using EBMUDSIM indicated it would substantially meet the temperature criterion in the river in all but 3 of the 70 years from 1921 to 1991. In the critical design drought, this alternative would result in a shortfall of water (or Need for Water) of 130 TAF.

4.2.2 Non-flow Strategies

As opposed to the operational strategies discussed in Section 4.2.1, non-flow strategies are improvement projects that, together with operational strategies, are intended to meet the stated LMRMP objectives. In general, flow strategies involve only the management of Pardee and Camanche reservoirs to meet water temperature requirements, without the additional expenditure of capital funds. In the following non-flow strategies, the objective is to recommend facility improvements to meet the dissolved oxygen requirements and eliminate the problems that lead to the formation of hydrogen sulfide in Camanche Reservoir.

Tables 4.1 and 4.2 summarize the non-operational alternatives and provide a guide to understanding the discussion of the non-flow management alternatives. Table 4.1 evaluates each of the alternatives with respect to reliability, operation and maintenance, and environmental sensitivity. If the alternative has a positive effect on any issue, an "x" appears in the column under that issue. When the alternative does not affect the issue (neutral), an "o" sign appears and, if it has an adverse (negative) effect, a "-" sign appears in the column. Table 4.2 lists each of the non-flow alternatives and indicates whether the Lower Mokelumne River, Camanche Reservoir, or the MRFH would benefit and which water quality goal would be benefitted by that alternative (t = temperature, o = dissolved oxygen concentration, and s = hydrogen sulfide).

4.2.2.1 Hypolimnetic Aeration Alternative

__Rationale__ - Hypolimnetic aeration was considered by EBMUD in an earlier report (EBMUD 1988). Aerating the hypolimnion of reservoirs increases the concentration of dissolved oxygen and eliminates hydrogen sulfide.

__Description__ - The proposed hypolimnetic aeration system(s) would be located upstream from the reservoir discharge point so that desired downstream concentrations of 7 milligrams/liter (mg/l) dissolved oxygen can be achieved with a minimum of aeration. This would provide at least 12 hours of contact time to oxidize hydrogen sulfide prior to discharge. A bench-scale

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Table 4.1. Summary of alternatives and the affected issues.

Alternative	Issues: Reliability	Operation and Maintenance	Environmental Sensitivity	Water Rights
Hypolimnetic aeration	o	-	-	x
Hypolimnetic oxygenation	x	-	o	x
Multi-level intake structure	o	o	x	x
River aeration plus treatment	o	-	-	x
Pardee Reservoir diversion	o	o	-	x
Mokelumne River pumping/diversion	o	o	-	x
Mokelumne Aqueducts diversion	-	o	-	-
Groundwater pumping	o	o	-	-
Floating pump station	-	o	o	x
Oxygen injection/hydrogen sulfide stripping	-	o	-	x
Ozone	o	o	-	x
Hydrogen peroxide	o	o	-	x
Ozone/hydrogen peroxide	o	o	-	x
Biological oxidation	-	-	o	x
Cooling towers/chillers	-	o	-	x

Legend: (Brown and Caldwell, CH2M-Hill 1992)
x = positive
o = neutral
- = negative

Table 4.2. Identification of benefits provided by each alternative.

Alternative	Benefit to: Camanche Reservoir	Mokelumne River	MRFH
Hypolimnetic aeration	o,s	o,s	o,s
Hypolimnetic oxygenation	o,s	o,s	o,s
Multi-level intake structure		t,o,s	t,o,s
Pardee Reservoir diversion	t,o,s	t,o,s	t,o,s
Mokelumne River pumping/diversion			o,s
Mokelumne Aqueducts diversion			t,o,s
Groundwater pumping			t,o,s
Floating pump station			o,s
Oxygen injection/hydrogen sulfide stripping			o,s
Ozone			o,s
Hydrogen peroxide			o,s
Ozone/hydrogen peroxide			o,s
Biological oxidation			o,s
Cooling towers/chillers			t

Legend:
o = Dissolved oxygen concentration water quality objective is met.
s = Hydrogen sulfide water quality objective is met.
t = Temperature water quality objective is met.

study of the hydrogen sulfide/dissolved oxygen reaction in Camanche Reservoir showed that a minimum of 12 hours was needed to fully oxidize hydrogen sulfide. Air would be pumped down into the hypolimnion where it would be mixed with hypolimnetic waters. Contact between the air and dissolved oxygen deficient waters of the hypolimnion would transfer oxygen into the water. Since air is 21 percent oxygen by volume, five times as much air would be required to raise the dissolved oxygen concentration than if pure oxygen were used. The major components of the aeration system would be a compressor and motor system, pipe distribution system, and floating-type bubble diffuser and/or mixer.

Evaluation - Aeration must preserve stratification. This strategy must balance the relative benefits of added downstream facilities (e.g., potassium permanganate treatment for hydrogen sulfide oxidation) against larger aeration capability in the reservoir. At Camanche, the thermocline cannot be allowed to break up early because, if the warm epilimnetic waters mix with the hypolimnion, water temperatures would increase.

Hypolimnetic aeration would benefit the reservoir and allow maximum power generation while meeting downstream release requirements. However, hypolimnetic aeration could lead to early destratification which, in turn, could increase release water temperatures. Meeting the downstream dissolved oxygen release requirements would benefit the river but, if the temperature increased, the release water would not meet the temperature requirements for the river and the MRFH. Furthermore, resuspension of bottom sediments in Camanche could increase the levels of turbidity in the release water.

Advantages

- Increases dissolved oxygen of release waters
- Eliminates hydrogen sulfide in release waters
- Relatively fast implementation
- Power generation from discharge to the river

Disadvantages

- Underwater construction difficult to locate and size
- Risk of destratification at high volume injection, increasing release water temperature
- May increase turbidity at higher injection rates
- Not reliable

4.2.2.2 Hypolimnetic Oxygenation

Rationale - Hypolimnetic oxygenation differs from hypolimnetic aeration in that pure oxygen is used in place of air. Less gas volume is required when using oxygen in place of air, so the likelihood of destratification in the reservoir is reduced. As with aeration, oxygenating the hypolimnion increases the dissolved oxygen concentration and eliminates hydrogen sulfide in water released from the hypolimnion; however, since the volume of gas used is lower, resuspension of bottom sediments is avoided.

Description - This proposed injection system would be located as near the outlet facility as possible to minimize the volume of the hypolimnion to be oxygenated, while allowing adequate travel time to provide at least 12 hours of contact time to oxidize hydrogen sulfide completely. The distribution/diffuser system would be smaller than a hypolimnetic aeration system because less oxygen would need to be injected to achieve desired dissolved oxygen levels. Liquid oxygen would be stored on site and could be converted to gas and piped to the diffusers without pumping.

Evaluation - The major benefits of hypolimnetic oxygenation are similar to those of hypolimnetic aeration, except that less injected gas is required and no compressors or pumps are needed to transfer oxygen. This method would not resuspend bottom sediments or destratify the reservoir, as would other types of aeration. Oxygenation will remove the hydrogen sulfide present.

Hypolimnetic oxygenation would benefit the reservoir because reservoir water could be discharged for power generation, the cold water fishery in the reservoir and the recreation use dependent on it would be enhanced, and the reservoir would remain stratified, all while meeting downstream release requirements. Maintaining cold temperatures in the hypolimnion would ensure no increase in release temperatures. Meeting the release temperature requirement and removing hydrogen sulfide will benefit the river and the MRFH.

Advantages

- Increases dissolved oxygen concentration of release waters
- Eliminates hydrogen sulfide
- Permits withdrawal of cold hypolimnetic waters; no increase in the temperature of release waters
- Less likelihood of sediment resuspension or destratification than with air injection for some types of delivery systems
- Relatively fast implementation
- Allows power generation

- Provides a benefit to reservoir, fishery, recreation use, river, and MRFH water quality

Disadvantages

- Difficult to locate and size
- Onsite oxygen storage and conversion facility required

4.2.2.3 Multi-level Outlet Structure

Rationale - The proposed multi-level outlet structure would allow water to be discharged from Camanche Reservoir from various elevations to meet water quality objectives at the MRFH and in the lower river. Use of this structure would partially resolve the hydrogen sulfide and low dissolved oxygen problems by allowing the dissolved oxygen-rich and warmer epilimnetic waters to be mixed with the dissolved oxygen-poor waters of the hypolimnion. The level of dissolved oxygen in Camanche release water would increase and hydrogen sulfide levels would decrease but may not be eliminated.

Description - The multi-level outlet structure would be designed to carry the full capacity of the river plus the MRFH feedwater supply. The inlet structure system would be a valved structure attached to the low level outlet tunnel/gate facility. The system would have a gated base configuration feeding both outlet tunnels from an intake tower that would lie along the north shore near the face of the dam on a concrete-steel support system. A series of valved intake extensions at 3-meter depth intervals would be used to withdraw water from elevations ranging from 58 meters above mean sea level (msl) to 36 meters msl. The low level north and south outlet tunnels at elevation 32 msl and the upper level outlet at elevation 62 msl would continue to operate.

Withdrawal port extensions and riprap around the tower base would be used to minimize the entrainment of sediment. A valved connection to the existing intake tunnel system would be required to preserve the full low-level withdrawal capability.

Evaluation - The benefit of the multi-level outlet structure would be the ability to withdraw and blend water from various elevations to meet the desired water quality objectives of the MRFH and the lower river. Currently, water can be withdrawn at only two elevations when the reservoir pool is full, and only from the bottom when the water surface elevation is below 61 meters. There are concerns that variability in withdrawal during the summer and the use of epilimnetic waters for mixing will not resolve the problems of hydrogen sulfide, low dissolved oxygen concentration, and temperature, since oxygen will be depleted and hydrogen sulfide will accumulate in most of the hypolimnion. The success of the system depends on the ability to avoid oxygen depletion or excessively warm water during reservoir stratification.

The multi-level outlet structure alternative may not eliminate the hydrogen sulfide problem without additional oxygenation or chemical treatment. The ability to release warmer water from the epilimnion in March and April would increase fish growth in the MRFH and promote early out-migration which would be beneficial.

<u>Advantages</u>

- Provides for flexible reservoir withdrawal operation, even during drought
- Minimizes use of water of less desirable quality
- Enables blending of epilimnetic and hypolimnetic waters
- Allows for release of warmer epilimnetic waters in March and April

<u>Disadvantages</u>

- Risk of not eliminating hydrogen sulfide problems without additional oxygen supplement or chemical treatment
- Not quickly implemented, requires difficult underwater construction

4.2.2.4 Aeration plus Potassium Permanganate for the Lower River

<u>Rationale</u> - Adding potassium permanganate into the MRFH feedwater supply lines has been sufficient to oxidize hydrogen sulfide (1990-1992). However, to meet the dissolved oxygen water quality requirement, the MRFH water must be aerated and the river release sluiced to increase the dissolved oxygen concentration of the raw water.

<u>Description</u> - Potassium permanganate is currently added in-line into the MRFH feedwater supply lines at a nominal dosage of 0.45 mg/l (dry weight basis) to oxidize hydrogen sulfide. Should it be necessary to remove hydrogen sulfide by chemical treatment, this dosage of potassium permanganate would probably be effective in eliminating hydrogen sulfide from the entire reservoir discharge, including the release to the river.

To treat the entire river release, potassium permanganate would be purchased as a bulk free-flowing solid in truck quantities, and stored in a hopper. Three tanks with mixers would be used to dissolve and feed the potassium permanganate. The permanganate solution would be pumped to the vicinity of the penstock with one of a pair of positive-displacement chemical feed pumps. The permanganate solution would be introduced in-line, into a slip stream, to provide dilution and better distribution of the permanganate solution within the penstock. Aeration would be required to increase the dissolved oxygen concentration.

The balance between reduced power generation with sluicing (via Howell-Bunger valves) versus additional aeration is a function of reservoir operations, available head, oxygen requirements, and power revenues. This alternative is logistically difficult and may not be technically feasible. The space and depth limitations would make it difficult to place enough aerators and platforms in the tailrace and river with the necessary power supply.

Evaluation - Treating the lower river with aeration and potassium permanganate would not improve the reservoir water quality. However, the permanganate solution would oxidize the hydrogen sulfide and aeration would increase the dissolved oxygen content of the downstream release, so the MRFH and the river would benefit. Under this alternative, the entire release from Camanche Reservoir would be treated. The handling and use of large quantities of potassium permanganate would be a disadvantage and the Regional Board may disagree with chemically treating the river release.

Advantages

- Eliminates hydrogen sulfide toxicity
- Increases dissolved oxygen
- Does not contribute to sediment resuspension within the reservoir

Disadvantages

- Large quantity of chemicals added to river
- Not proven reliable under continuous operation or with quantities required to treat entire river flow
- No benefit to reservoir water quality

4.2.2.5 Pardee Reservoir Diversion

Rationale - Even in drought years, water released from the Pardee Reservoir hypolimnion is cold and high in dissolved oxygen. Diverting flows from Pardee Reservoir to Camanche Dam through a pipeline would alleviate the water quality problems associated with the warming of the Camanche outflow, as long as the Pardee hypolimnion was not depleted.

Description - To divert water from Pardee Reservoir, water would be transferred through a new outlet facility equipped with a large-diameter pipeline that would supply the water to the deep water area in front of Camanche Dam. In this way, a portion of the diverted water could be discharged to the Camanche hypolimnion when the quantity of diversion was higher than the discharge required from Camanche to the river. The diversion pipeline, if operated this way, would serve as an alternate means of releasing Pardee water into Camanche Reservoir. This would alleviate the problem of the Pardee release becoming too warm before reaching the main body of Camanche Reservoir.

Evaluation - This project would improve temperature stratification in Camanche Reservoir if the water diverted in excess of the downstream release needs were discharged into the main body of Camanche Reservoir. Since this alternative would permit Pardee and Camanche waters to be mixed, the temperature, hydrogen sulfide toxicity, and dissolved oxygen requirements might be met to benefit the river and the MRFH. When Camanche water has a high level of hydrogen sulfide making it unsuitable for blending with Pardee diversion water to provide a non-toxic blend for discharge to the river, all the Camanche release would have to be drafted from Pardee and would deplete Pardee storage. The advantages and disadvantages of this concept are:

Advantages

- Compared to previous alternatives, this alternative is relatively maintenance free
- Could help maintain Camanche stratification

Disadvantages

- Would deplete Pardee storage when Camanche water is not suitable for blending
- Need for extensive large-diameter pipeline and underwater placement make construction complicated
- Long-term implementation period
- Expensive construction
- May cool the Camanche Reservoir outlet temperature too much

4.3 MOKELUMNE RIVER FISH HATCHERY NON-FLOW STRATEGIES

4.3.1 Mokelumne River Pumping/Diversion

Rationale - Historical data from Station 11 in the Mokelumne River just downstream of Camanche Dam (Miyamoto, 1989) show that release waters are fully oxygenated following discharge through the sluiceways and/or Howell-Bunger valves. This alternative would directly address the MRFH dissolved oxygen problem by extracting higher dissolved oxygen water from the river and pumping it through the MRFH.

Description - By locating a diversion and pump station upstream of the MRFH discharge, oxygenated waters can be used as feedwater for the MRFH without recirculating the discharge. Recirculation of MRFH discharge water should be avoided as much as possible because of the possibility of recirculating fish diseases. Additional piping and modification of the present outlet facilities would be required to meet this consideration and intake water may need to be sterilized. The intake should be placed to avoid pumping MRFH return waters. This alternative would require a side channel structure that would divert water into a wet-well pump station facility, pipeline, sterilization facility, and discharge/outfall structure (aeration tank is a possibility).

Evaluation - The pumping/diversion alternative would return river water to the MRFH so there would be no direct benefit to the river; however, the requirements for temperature and dissolved oxygen concentration downstream would be met. There is some concern that hydrogen sulfide toxicity in the release waters would continue to be a problem under this alternative. Therefore, the benefit to the MRFH would not be sustained throughout the entire year and, although the MRFH would receive water high in dissolved oxygen, the water may not be sulfide free. Since the reservoir is not affected by this alternative, there is no direct benefit to the reservoir.

Advantage

- Access water high in dissolved oxygen
- Provides a water quality benefit to the MRFH

Disadvantages

- A potential for increased fish disease problems
- No treatment for hydrogen sulfide; risk of not meeting the toxicity water quality goal
- MRFH outlet may need to be relocated
- Requires sluicing instead of power generation
- No water quality benefit to the reservoir or the river
- Reliance on pumping for water supply would require a fail-safe pump duplication system

4.3.2 Mokelumne Aqueducts Diversion

Rationale - This proposed alternative is designed to take advantage of the better water quality conditions found in Pardee Reservoir throughout the year and the proximity of the Mokelumne Aqueducts to the MRFH (about 6.4 km). The important benefits of this alternative would be the year-round availability of oxygenated water free of hydrogen sulfide; however, the water temperature would be greater.

Description - The Mokelumne Aqueducts diversion would provide flow only to the MRFH through a gravity flow facility from a diversion structure connected to the aqueducts. The plan would require a valved diversion off the Mokelumne Aqueducts, a pipeline, an outlet/discharge structure at the MRFH, and treatment to dechlorinate, adjust the pH, and cool the water prior to use by MRFH. Aqueduct waters are pretreated (chlorination and corrosion control) as they leave Pardee Reservoir. Both treatment practices would continue because the contact time in the pipeline is used to meet the disinfection requirements mandated by the Surface Water Treatment Rule. Corrosion control practices would be continued for proper maintenance of the aqueducts.

Evaluation - The disadvantage of this alternative is that the water would have to be treated to adjust the pH, remove chlorine, and reduce the water temperature, and head pressure would have to be dissipated. The Mokelumne Aqueducts diversion alternative provides no benefit to Camanche Reservoir. The MRFH would benefit because water high in dissolved oxygen and free of hydrogen sulfide would be provided to the facility. The effects of the additional discharge to the river would be minimal and the river would not benefit from this alternative.

Advantages

- Access water high in dissolved oxygen and free of hydrogen sulfide
- Reliable water quality benefit to MRFH

Disadvantages

- Decreases the delivery capacity/yield of the aqueducts
- Chemical treatment and pH adjustment required
- Process cooling would be required
- Head dissipation needed
- No benefit to water quality in Camanche Reservoir or Lower Mokelumne River
- Expensive construction

4.3.3 Groundwater Pumping

Rationale - Preliminary estimates indicate that a well field of 10 wells near the dam would provide about 4 cfs of ground water with dissolved oxygen concentrations and temperatures sufficient to meet the water quality goals of the MRFH.

Description - This alternative would provide water to the MRFH through the development of a well field with an estimated 10 wells near the dam, possibly adjacent Van Assen Park. These wells would be used for blending between June and October when water quality in Camanche Reservoir is poor and between February and April when increased water temperature is a rearing benefit. Monitoring of the groundwater table, drawdown and recovery curves, infiltration rates, and capacity tests are necessary to define the size, location, depth, and number of wells needed to supply the feedwater required by the MRFH. A production well is currently being designed to better define these factors.

Evaluation - Pumping tests conducted to provide preliminary information on safe yields from drainage wells located at the foot of Camanche Dam indicate that the quantity of ground water available is insufficient to supply the entire flow required by the MRFH (Brown and Caldwell 1992). The groundwater alternative could only supplement the existing supply. This alternative would not directly benefit the reservoir and, since there are no provisions to remove hydrogen sulfide from the reservoir release water, this alternative would not benefit water quality in the river.

Advantages

- Possible access to high dissolved oxygen, hydrogen sulfide-free water
- Water quality benefit to the MRFH
- Water temperature to the MRFH at critical rearing times

Disadvantages

- Possible groundwater drawdown concerns
- Ground water of unknown long-term quality
- Temperature requirements may not be met
- Only a supplemental source of water for the MRFH
- No water quality benefit to the reservoir or the river

4.3.4 Floating Pump Station (Existing)

Rationale - The floating pump station is a temporary facility constructed by EBMUD to occasionally access better quality water for the MRFH than that provided by the lower level Camanche Reservoir outlet. This is a tested alternative that provides water meeting the water quality objectives of the MRFH.

Description - EBMUD installed a floating pump station upstream of the dam in Camanche Reservoir that pumps between depths of 9 and 15 meters below the surface. Water is pumped into the upper level outlet tower and passed by gravity flow to the valve control house. The ability to withdraw water of desired quality is a substantial benefit during critical water quality periods.

Since the equipment and fabricated connections to the upper level intake are available, the capital costs of this alternative would be limited to increasing pumping capacity and anchoring a floating barge in place.

Evaluation - The floating pump station alternative does not benefit the river or reservoir because the hydrogen sulfide problem would not be solved. Only the MRFH benefits from this alternative as the temperature, hydrogen sulfide, and dissolved oxygen water quality problems are addressed.

Advantages

- Possible access to higher quality water for the MRFH
- Basic pumping system is in place
- Benefits the water quality of the MRFH

Disadvantages

- May not access hydrogen sulfide-free water
- No benefit to reservoir water quality
- No benefit to quality of water released to the river

4.3.5 Oxygen Injection/Hydrogen Sulfide Stripping

Rationale - The oxygen injection/hydrogen sulfide stripping supplemental alternative was developed for use on the MRFH feedwater supply stream. To meet the dissolved oxygen concentration and hydrogen sulfide water quality goals, hydrogen sulfide would be stripped from the MRFH influent in a packed tower. This would be followed by injection of pure oxygen to raise the dissolved oxygen concentration.

Description - The initial step would be to strip hydrogen sulfide from the MRFH influent in packed columns, which are more efficient in removing dissolved gases than the existing spray aeration system. Stripping would be followed by injection of pure oxygen to raise the dissolved oxygen concentration of the feedwater to a minimum of 7 mg/l.

Evaluation - Limited experience with packed towers used for nitrogen stripping suggests that these devices may not remove enough hydrogen sulfide for MRFH feedwater use. At a minimum, it would be necessary to reduce the pH to approximately 5 and to readjust it to neutrality after stripping. (Supplemental oxidation may also be needed to assure adequate removal.)

Producing treated water sufficiently low in hydrogen sulfide to be suitable as feedwater to the MRFH may not be technically feasible with this supplemental alternative. The secondary benefit of providing oxygen-enriched feedwater, however, does appear technically attainable.

The oxygen injection/hydrogen sulfide stripping alternative treats only the flow to the MRFH, so only the MRFH benefits from the improved water quality. The river and the reservoir will not benefit from this alternative because the hydrogen sulfide and dissolved oxygen problems in those bodies of water are not addressed under this alternative.

<u>Advantages</u>

- Increases dissolved oxygen
- Strips some hydrogen sulfide

<u>Disadvantages</u>

- May not completely remove hydrogen sulfide
- Technically difficult process
- Supplemental oxygen supply required
- No solution or benefit to the river or reservoir water quality problems

4.3.6 Ozone

<u>Rationale</u> - Ozone is a powerful and fast-acting oxidant that reacts immediately with sulfide. In this application, ozone would be used as a treatment process to oxidize and remove sulfide from the MRFH influent.

<u>Description</u> - Ozone would be generated onsite from air and dissolved in the MRFH feedwater supply in a mechanically-mixed, contact chamber downstream from the existing aerator. The point of application would prevent the ozone from becoming stripped into the atmosphere as the feedwater supply is aerated. The ozonation system would include air preparation to dehumidify incoming air and remove dust and airborne particulate matter, an ozone generator, and a contact chamber equipped with a turbine mixer to provide efficient absorption and distribution throughout the treated feedwater supply. The applied ozone dose would be 0.3 mg/l, based on the oxidant dosing currently used for potassium permanganate.

<u>Evaluation</u> - The primary benefit of treating the MRFH feedwater supply with ozone would be the oxidation of hydrogen sulfide. Ozone is usually not used for this purpose because it is expensive and aquatic organisms may not tolerate concentrations above 0.02 mg/l.

The ozone alternative treats only flow to the MRFH, so only the MRFH would benefit from the improved water quality. Neither the river nor the reservoir would benefit from this alternative because the hydrogen sulfide and dissolved oxygen problems in those bodies of water are not addressed under this alternative.

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Advantages

- Easy on-site generation and mixing
- Hydrogen sulfide oxidation
- May meet the temperature release requirements

Disadvantages

- Possible toxicity problems
- No improvements to reservoir water quality
- No improvements to water quality in downstream releases
- Potential impacts to on-site biological filters and river invertebrates

4.3.7 Hydrogen Peroxide

Rationale - Hydrogen peroxide, like ozone, is a strong oxidant that removes sulfide by converting it to elemental sulfur or sulfate. Hydrogen peroxide, however, does not oxidize as quickly as ozone, even though the end result may be similar.

Description - Hydrogen peroxide would be injected into the MRFH feedwater supply line at the valve house. This injection point would provide at least part of the residence time needed for hydrogen peroxide to react before the flow supply reaches the MRFH. Hydrogen peroxide solution would be fed at a manually-controlled flow rate by positive displacement chemical feed pumps.

Evaluation - Hydrogen peroxide effectively eliminates hydrogen sulfide by oxidizing it to elemental sulfur or sulfate, and has been used successfully to control hydrogen sulfide in large municipal wastewater collection systems. This chemical has not been as extensively marketed as a treatment chemical for fish rearing facilities as has potassium permanganate. However, the limited toxicity information available for hydrogen peroxide indicates that aquatic organisms such as fingerling trout, *Daphnia magna*, and channel catfish can tolerate short-term exposure to 30 - 40 mg/l of hydrogen peroxide. This suggests that the 1 mg/l dosage proposed for hydrogen sulfide control should not interfere with operation of the hatchery.

The hydrogen peroxide alternative treats only flow to the MRFH, so only the MRFH would benefit from the improved water quality. Neither the river nor the reservoir would benefit from this alternative because hydrogen sulfide and dissolved oxygen problems in those bodies of water are not addressed under this alternative.

Advantages

- Hydrogen sulfide oxidation
- Ease of storage and operation
- Provides the MRFH with water that meets the water quality goals of the MRFH

Disadvantages

- Limited toxicity information
- No improvements to reservoir water quality
- No improvements to water quality in downstream releases
- Potential impacts to on-site biological filters and river invertebrates

4.3.8 Ozone/Hydrogen Peroxide

Rationale - The ozone/hydrogen peroxide alternative is conceptually similar to the previously described ozone alternative. In this alternative, ozone would be added at the same dose as in the previous case (0.28 mg/l), but hydrogen peroxide would also be added to increase the short-term oxidizing potency, while eliminating the residual ozone concentration.

Description - The ozone and hydrogen peroxide chemical and gas generating systems would inject the oxidants into the MRFH feedwater, just downstream of the existing aerator. The point of application would prevent the ozone from becoming stripped into the atmosphere as the feedwater supply is aerated. The ozonation system includes air preparation to dehumidify incoming air and remove dust and airborne particulate matter, an ozone generator, and a contact chamber equipped with a turbine mixer to provide efficient absorption and distribution throughout the treated feedwater supply. Hydrogen peroxide solution would be fed at a manually-controlled flow rate by positive displacement chemical feed pumps.

Evaluation - The benefits achieved with ozone/hydrogen peroxide treatment would be the same as for ozone alone, but the potential for ozone toxicity would be eliminated. The ozone/hydrogen peroxide system would necessitate the management and expense of two chemical feed systems, but the hydrogen peroxide dosage would be about half the ozone dosage (weight basis), which is far below the dosage required for hydrogen peroxide alone.

The ozone/hydrogen peroxide alternative treats only the flow to the MRFH, so only the MRFH would benefit from the improved water quality. Neither the river nor the reservoir would benefit from this alternative because the hydrogen sulfide and dissolved oxygen problems in those bodies of water are not addressed under this alternative.

Advantages

- Hydrogen sulfide oxidation
- Eliminates ozone toxicity
- Reduces hydrogen peroxide dosage
- May meet the temperature release requirements

Disadvantages

- Two complex chemical feed systems needed
- No improvements to reservoir water quality
- No improvements to water quality in downstream releases

4.3.9 Biological Oxidation

Rationale - Biological oxidation would eliminate oxygen-consuming compounds in the reservoir water, facilitating maintenance of a dissolved oxygen residual suitable for MRFH operation. Secondarily, hydrogen sulfide could be removed through a combination of volatilization and oxidation in this alternative.

Description - Biological oxidation of the MRFH feedwater supply would be carried out in a fixed-film bioreactor, sized to treat the entire MRFH stream. A fixed-film process would be used because the biological oxygen demand (BOD) is expected to be low (50 mg/l or less). For purposes of discussion, a trickling filter loaded at 15 pounds of BOD per 1,000 cubic feet has been assumed, with no supplemental nutrients provided. It was further assumed that clarifiers would not be needed and that treated water would be sent directly to the MRFH.

Evaluation - The primary benefit of biological oxidation would be that oxygen-consuming constituents in the reservoir water would be eliminated, facilitating maintenance of a dissolved oxygen residual suitable for MRFH operation. A secondary benefit of this alternative would be that hydrogen sulfide could be removed through a combination of volatilization and oxidation. It is doubtful that hydrogen sulfide toxicity could be completely eliminated with this system.

The biological oxidation alternative treats only the flow to the MRFH, so only the MRFH would benefit from the improved water quality. Neither the river nor the reservoir would benefit from this alternative because the hydrogen sulfide and dissolved oxygen problems in those bodies of water are not addressed under this alternative.

C-100817

Advantage

- Reduced biological oxygen demand, higher dissolved oxygen

Disadvantages

- Incomplete hydrogen sulfide removal
- Questionable reliability because of noncontinuous use
- Risk of not meeting temperature release requirements
- No improvements to reservoir water quality
- No improvements to water quality in downstream releases

4.3.10 Cooling Towers/Chillers

Rationale - This alternative is developed to provide a process for cooling MRFH feedwater whenever that becomes necessary.

Description - Water from the valve house at the foot of Camanche Dam would be diverted from the Camanche release and passed through a series of cooling towers and then to a chiller prior to entering the MRFH. The mechanics of cooling surface water with temperatures ranging from 21 to 27°C may be limited without including a direct chilling process. Preliminary investigations using 25°C surface water and outside air temperature of 38°C, and a relative humidity of 15 percent resulting in a minimum water temperature of 18°C without the chilling loop. By including a chiller loop for part of the flow stream (about 20 cfs) and mixing this directly with epilimnion waters, the feedwater temperature goal could be maintained. Several combinations of cooling tower and chiller flow splits could be applied to achieve the desired temperature control for the MRFH feedwater.

Evaluation - The cooling towers/chillers alternative would treat only the flow to the MRFH, so only the MRFH would benefit from the improved water quality. Neither the river nor the reservoir will benefit from this alternative because the hydrogen sulfide and dissolved oxygen problems in those bodies of water are not addressed under this alternative.

Advantage

- Meets water quality objectives for temperature

Disadvantages

- Complex control operation
- Requires ability to access surface water

- Reliability is critical
- No improvements to reservoir water quality
- No improvements to water quality in downstream releases
- High operation and maintenance costs
- Unproven technology of this size proposed

4.4 MOKELUMNE RIVER

Several alternatives were evaluated to develop the Lower Mokelumne River Management Plan. A production-oriented approach with an emphasis on natural production was ultimately selected as the preferred alternative because it best balances the fishery benefits with other water management concerns. This approach is described and compared to the CDFG Plan in greater detail in Section 5.0.

The alternatives differ in terms of flows provided for in-river production, operation of the MRFH, and resulting levels of smolt production, natural smolt production, yearling production, harvest, overall Central Valley escapement, and escapement to the Mokelumne River. (Terms are defined in Appendix E). The alternatives are summarized in Table 4.3 and described in detail in the following sections.

It is difficult to evaluate the potential effects of management alternatives because of incomplete knowledge of the fish populations involved and the mechanisms which regulate them. Although this analysis uses the best information currently available, it must be recognized that management decisions based on incomplete information may be inaccurate. Therefore, a management strategy that incorporates flexibility and maximizes options is going to be the most effective at achieving management goals (Section 2.0). Section 6.0 describes a plan for monitoring and research that will improve the information base.

Two tools were used to evaluate management alternatives: a habitat based model (SCIES) and a simple population-based model. The SCIES model uses habitat/flow relationships developed by CDFG using the Instream Flow Incremental Methodology (IFIM) and temperature/flow relationships developed by BioSystems using the USFWS Stream Network Temperature Model (SNTEMP). The life cycle model is a population model using data and assumptions generated by the USFWS, CDFG, EBMUD and others. Both of these models are planning tools; they do not predict actual numbers of fish. They are useful in comparing the different management alternatives in terms of their potential fishery benefits *based on the existing information*. The models are described fully in Appendix D (SCIES) and Appendix E (Life cycle model).

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Table 4.3. Comparison of in-stream management alternatives for Lower Mokelmune River salmon and steelhead fisheries.

	CDFG	ESCAPEMENT	PRODUCTION/ NATURAL	PRODUCTION/ HATCHERY	HARVEST	1961 AGREEMENT
Escapement Goals						
Chinook salmon (adult)	15,000	5,000				
Steelhead trout (adult)	2,000					
MRFH Production						
Salmon smolts, Delta	2,000,000	1,400,00	3,200,000	3,300,000		1,400,000
Salmon smolts, river			up to 460,000[1]	370,000		
Salmon yearling, Delta		530,000			4,500,000	530,000
Salmon yearling, river	1,500,000		800,000	800,000		
Steelhead trout	100,000	53,000	53,000	53,000		53,000
River Habitat						
Spawning	chinook: 80% of maximum WUA in dry years; 100% of maximum in normal and wet years	chinook: 55% of maximum WUA in critical years; 90-100% of maximum in dry normal and wet years	chinook: 55% of maximum WUA in critical years; 80% in dry years and 100% in normal and wet years	chinook: 55% of maximum WUA in critical years; 55%-70% in all others	chinook: 55% of maximum WUA in critical years; 80% in dry years and 100% in normal and wet years	chinook: 100-125 cfs, 55-60% of maximum WUA
Rearing	200-450 cfs; 82-54% of maximum WUA	100-300 cfs; 100-77% of maximum WUA	100-200 cfs; 80-100% of maximum WUA	100-150 cfs; 80-100% of maximum WUA	100-200 cfs; 80-100% of maximum WUA	90-200 cfs, 80-100% of maximum WUA
Out-migration	reservation of 10,000 acre-feet in wet and 5,000 af in dry years for short duration releases. Flows not enough for temperature control; no trap and truck	Flow to control temperature through June in normal and wet year and through May in dry years; trap and truck at other times	Flow to control temperature through June in normal and wet year and through May in dry years; trap and truck at other times	No outmigration flow; no temperature control; trap and truck	Temperature control to Lake Lodi, no outmigration flow below Woodbridge Dam; trap and truck	No outmigration flow required; trap and truck
Year Type Frequency	Based on runoff; historic record is: dry 14%, normal 47%, wet 39%	Based on runoff and storage; EBMUDSIM projection is: critical 20%, dry 27%, normal 11%, wet 41%	Based on runoff and storage; EBMUDSIM projection is: critical 16%, dry 34%, normal 36%, wet14%	Based on runoff and storage; EBMUDSIM projection is: critical 46%, other 54%	Assumed to be the same as production/natural: critical 16%, dry 34%, normal 36%, wet 14%	Based on runoff; historic record is: dry 14%, normal 47%, wet 39%

[1] Depends on size of Mokelumne run.

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The findings presented in Section 3.0 lead to the following general conclusions regarding management of the Mokelumne River stock:

- Under existing conditions, escapement to the Mokelumne includes large numbers of strays.
- Returns of Mokelumne-origin fish to the Mokelumne can be improved by changing the management of both the river and hatchery.
- Increasing natural production in the river has an upper limit determined by the natural carrying capacity of the system; on the other hand, hatchery production can be increased but survival is limited by management procedures and external factors.
- Improving conditions for out-migration of naturally-produced fish and releasing more of the hatchery production in the river will increase returns to the Mokelumne; releasing more fish in the Delta should increase ocean harvest and overall returns to the Central Valley but will not greatly increase the number of fish returning to the Mokelumne.
- In general, yearling fish releases in the Mokelumne result in greater numbers of salmon caught and salmon returning to spawn than an equivalent number of smolt releases.

The alternatives presented in this chapter are based on these conclusions but each has different goals and strategies. The CDFG Plan is based on the results of CDFG-sponsored studies on the river. It would attempt to increase average Mokelumne River salmon and steelhead runs by optimizing river habitat and releasing yearling salmon in the river during the fall. Under this alternative, ocean harvest would be supported by releasing hatchery smolts below the Delta.

If no changes are made on the river, the 1961 CDFG agreement would remain in effect. It includes 13,000 acre-feet of water for fishery purposes to be used at the discretion of CDFG, in addition to all other releases for meeting downstream water uses and entitlements.

Four alternatives were developed for EBMUD, each focusing on the enhancement of a specific portion of the salmon's life cycle, while making some provision for steelhead. The first of these alternatives (escapement-oriented) focuses on enhancing spawning escapement in the Mokelumne River, while maintaining current hatchery and fishery management practices. The central strategy of this alternative is to use high flow releases during the upstream migration period to attract fish (mostly strays from other rivers) into the Mokelumne. Flow would be optimized for in-river production during other periods, although this is not necessary for this scenario to succeed.

The second (and preferred) alternative (production-oriented, natural-emphasis) focuses on optimizing natural in-river production. This alternative would change the way the MRFH is managed to increase the return rate of fish that originated in the Mokelumne. Ocean harvest would be supported by importing eggs or fry from other hatcheries, rearing them separately from those fish of Mokelumne origin, and releasing production below the Delta.

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Under the third alternative (production-oriented, hatchery- emphasis), the MRFH would be operated as with the previous alternative, but only a baseline level of natural in-river production would be provided.

The fourth alternative (harvest-emphasis) would provide a baseline level of natural in-river production and the same level of production at the MRFH as the previous two alternatives. However, all salmon would be released as yearlings below the Delta to maximize ocean harvest.

The alternatives described above encompass a broad range of flow commitments and fishery benefits and allowed exploration of the relative effects of different flow scenarios and operational parameters for the MRFH.

The CDFG Plan and the 1961 CDFG agreement (base case) differ from the other four alternatives developed for EBMUD in the way they define water year types for fish flow releases. The CDFG Plan and the base case use the projected runoff from the Mokelumne River Basin Watershed. Under this classification, dry year flows are provided when the projected runoff is less than 50 percent of the historical mean average, and wet year flows are provided when the projected runoff is more than 110 percent of the historical average. Although the CDFG does not explicitly describe how this would be implemented, it is assumed that a decision would be made in April or May for the following year's operation. According to the historical record (1921-1990), dry, normal, and wet years occur about 16 percent, 46 percent, and 38 percent of the time, respectively.

The four EBMUD alternatives define water year type by using a combination of Mokelumne River Watershed Basin runoff and the combined storage of Camanche and Pardee reservoirs. Under this system, fish-flow release decisions are made at two key times during the year. In April, water supply conditions through the following October can be accurately predicted based on projected runoff determined from snow-pack surveys. In November, decisions can be reconsidered when the actual end-of-October storage is known.

For 15 April - 31 October, wet/normal year fish flows are provided when the combined Pardee/Camanche storage is projected to be at the maximum levels allowed by the COE's flood space reservation requirement on 5 November (this amount varies by storage conditions in PG&E's reservoirs upstream of Pardee; see flood reservation requirement in Section 5.0). Dry year releases for fish are made if the combined Pardee/Camanche storage is projected to be below the flood space reservation requirement on 5 November. If projected Pardee/Camanche storage will be less than 260 TAF below the maximum flood space reservation on 5 November, critical dry year flows are provided.

For the period 1 November-14 April, fish releases are based on actual 5 November storage. The criteria are the same as those discussed above. If, during any month, inflow conditions are such that flood control releases must be made, releases for fish are increased up to the appropriate wet year level until flood control releases cease. Any remaining release necessary to prevent storage from encroaching into the flood control space reservation is classified as a flood control release.

Because each alternative has different flow scenarios and release schedules influence storage, the frequency of year types differs for each alternative. By using storage conditions in addition to runoff projections, this approach is more flexible and can adapt to changing conditions of supply. Furthermore, overcommitment of resources during times of potential shortages can be avoided. For this alternative to be implemented, however, EBMUD, CDFG, and other resource agencies would have to agree on explicit operational rules.

The CDFG Plan also differs from the four EBMUD alternatives in terms of water temperature criteria (there are no temperature criteria in the 1961 CDFG agreement) (Table 4.4). The main difference is that the CDFG Plan specifies a 13.3°C temperature goal to be met at Elliott Road during spawning and incubation, while the others have a goal of 14°C at Mackville Road. Conditions in the river are such that the lower station at Elliott Road will usually meet the 13.3°C temperature criteria during this period. In addition, the CDFG Plan specifies a goal criterion of 15.6°C during out-migration through the lower reach in April and May, while the other plans have an 18°C criterion. A review of the literature on chinook salmon temperature preferences and a rationale for these criteria are presented in Section 3.0.

It is not clear how the CDFG Plan proposes to meet its water temperature criteria or what actions will be taken if the criteria are not met. The other EBMUD alternatives have developed flow conditions that would, in general, allow them to meet their stated water temperature criteria (based on temperature-modeling studies, Appendix C); however, these alternatives acknowledge it is not always possible to meet such criteria. For example, temperature criteria for the fall upstream migration and spawning period are determined primarily by air temperature and secondarily by Camanche Reservoir release temperature. The release rate of Camanche has little effect on water temperature in the spawning reach (Figure 4-1). In the late out-migration period (end of June), it is sometimes impossible to meet the desired water temperature criteria below Woodbridge at flow levels of 1,000 cfs or less. Also, at this time of year, flow increases reduce water temperature only up to a certain level; further flow increases have little incremental effect (Figure 4-2). In these cases, the flow providing the coolest water temperature before the point of diminishing return was selected. Water temperature was above the optimal level but in the higher suitability ranges. Because the temperature criteria presented generally fall within the upper optimal range for the life-stage, losses are not likely to occur if the criteria are exceeded by a degree or two. A complete sensitivity analysis and documentation of the extent and magnitude of thermal conditions that exceed the LMRMP criteria for the selected alternative are presented in Appendix C (Stream Network Temperature Model [SNTEMP] Methodology).

Two BioSystems models were used to evaluate the benefit of each alternative to fishery resources (particularly chinook salmon). The SCIES model expresses habitat conditions (including temperature) as a score from 0 to 100 for each life-stage of chinook salmon and steelhead. The life cycle model estimates chinook salmon smolt and yearling production, the

Table 4.4. Comparison of management alternative temperature criteria.

		CDFG		OTHERS	
		TEMPERATURE (°C)	LOCATION	TEMPERATURE (°C)	LOCATION
NORMAL/WET					
October	1	18.3	Hwy. 99	18	Elliott Rd.
	2	13.3	Elliott Rd.	14	Mackville Rd.
November		13.3	Elliott Rd.	14	Mackville Rd.
December		13.3	Elliott Rd.	14	Mackville Rd.
January		13.3	Elliott Rd.	14	Mackville Rd.
February		13.3	Elliott Rd.	14	Mackville Rd.
March		13.3	Elliott Rd.	14	Mackville Rd.
April		15.6	Cosumnes	18	Ray Rd.
May		15.6	Cosumnes	18	Ray Rd.
June		18.3	Hwy. 99	18	Ray Rd.
July		18.3	Hwy. 99	18	Elliott Rd.
August		18.3	Hwy. 99	18	Elliott Rd.
September		18.3	Hwy. 99	18	Elliott Rd.
DRY					
October	1	18.3	Hwy. 99	18	Elliott Rd.
	2	18.3	Hwy. 99	14	Mackville Rd.
November		13.3	Elliott Rd.	14	Mackville Rd.
December		13.3	Elliott Rd.	14	Mackville Rd.
January		13.3	Elliott Rd.	14	Mackville Rd.
February		13.3	Elliott Rd.	14	Mackville Rd.
March		13.3	Elliott Rd.	14	Mackville Rd.
April		18.3	Cosumnes	18	Ray Rd.
May		18.3	Cosumnes	18	Ray Rd.
June		18.3	Hwy. 99	18	Hwy. 99
July	1	18.3	Hwy. 99	18	Hwy. 99
	2	18.3	Hwy. 99	18	Elliottt Rd.
August		18.3	Hwy. 99	18	Elliottt Rd.
September		18.3	Hwy. 99	18	Elliottt Rd.
CRITICAL DRY					
October	1			18	Elliott Rd.
	2			14	Mackville Rd.
November				14	Mackville Rd.
December				14	Mackville Rd.
January				14	Mackville Rd.
February				14	Mackville Rd.
March				14	Mackville Rd.
April				18	Hwy. 99
May				18	Hwy. 99
June				18	Hwy. 99
July	1			18	Hwy. 99
	2			18	Elliott Rd.
August				18	Elliott Rd.
September				18	Elliott Rd.

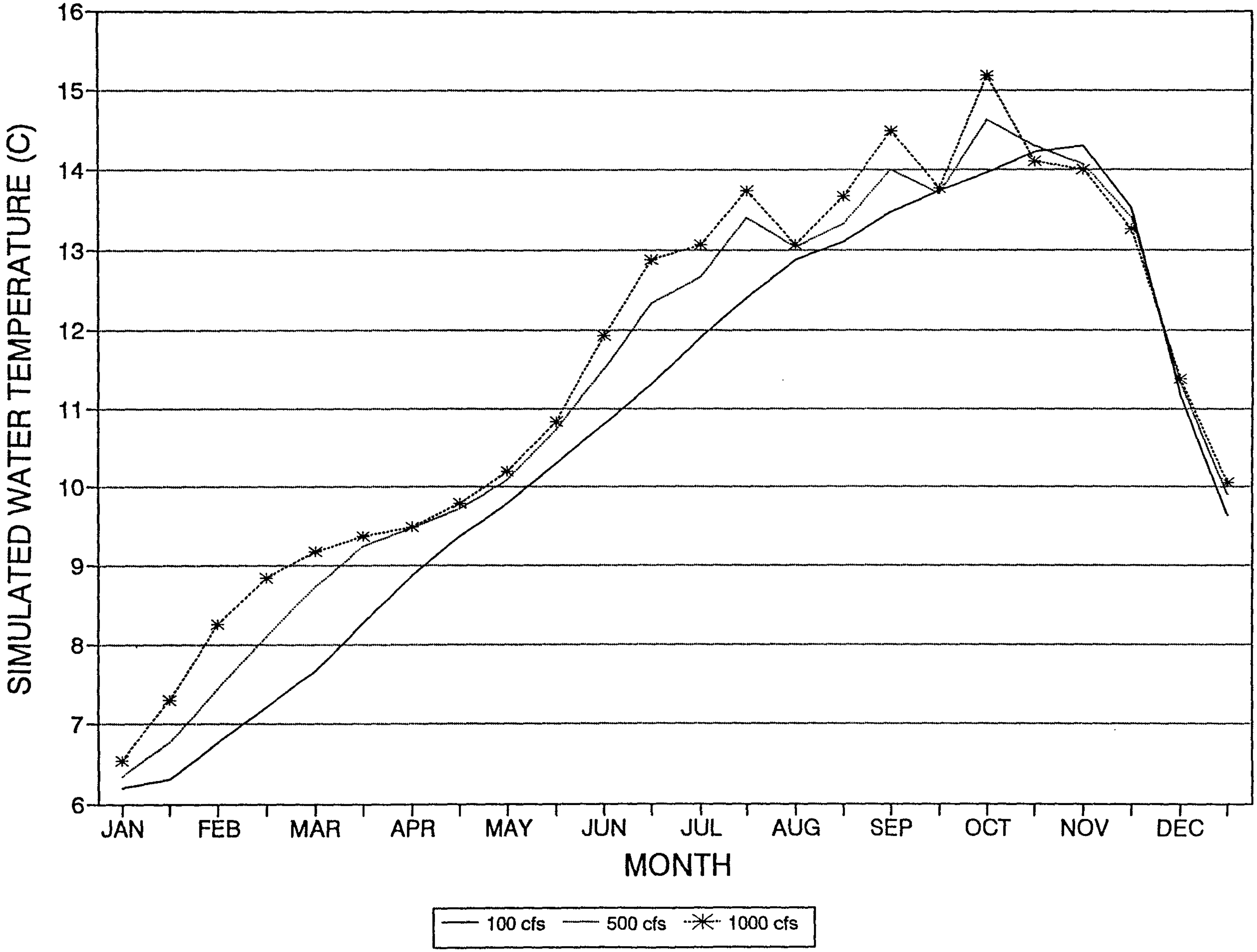

Figure 4-1. Simulated release water temperature for the Mokelumne River below Camanche Dam.

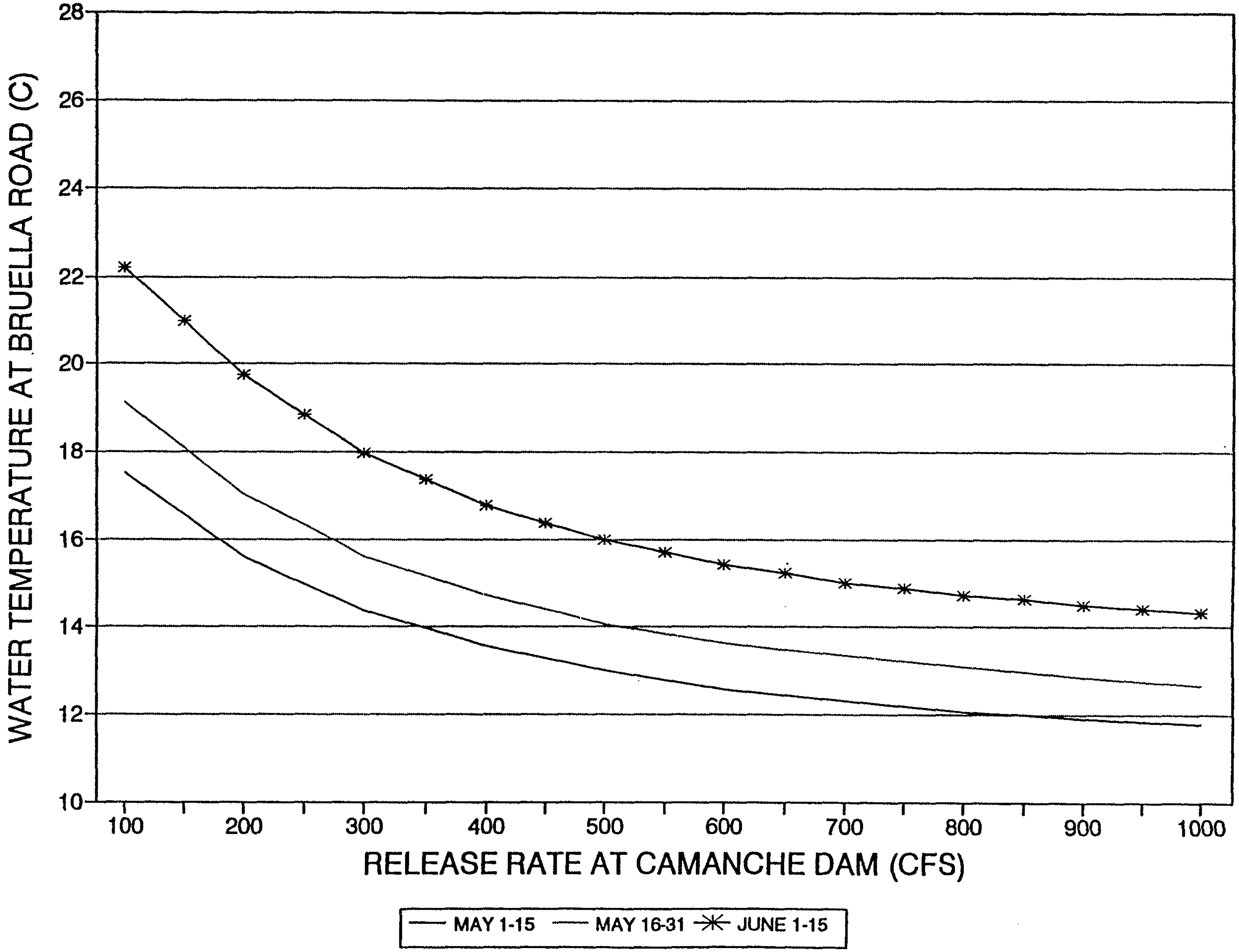

Figure 4-2. Simulated water temperature at Bruella Road during the heating period.

contribution to ocean fisheries, and the return of spawners to the Mokelumne and other Central Valley streams. The SCIES model is documented and its results are presented in Appendix D; the life cycle model documentation and results are presented in Appendix E.

All alternatives were first evaluated on the basis of their recommended flow schedules. If any of the alternatives were implemented under existing demand, it is likely the river would receive more water than specified by the flow schedule, particularly in normal and wet years, because of the inability to store excess flows. In addition, since releases are made from Camanche Dam during the irrigation season and then diverted again at the WID Canal, it is often necessary to release water well in excess of fishery needs in the reach above the WID Canal to meet flow needs in the river below the canal. Therefore, alternatives also were evaluated under these implementation flows. The implications of the preferred alternative and the CDFG Plan are explored more fully in Section 5.0.

4.4.1 Existing Conditions: the CDFG 1961 Agreement

The CDFG and EBMUD managed the river under CDFG's 1961 agreement until 1991. The agreement assumed that EBMUD would maintain releases below Camanche Dam similar to those that occurred before the dam was built. In addition, the state reserved 5,400 acre-feet in critical dry years and 13,000 acre-feet in other years for the downstream fisheries in addition to all other release requirements (125 TAF). The flow schedule presented in Table 4.5 represents EBMUD's projection of how Camanche releases would be made to meet downstream needs in compliance with the 1961 agreement.

There is some question about what the actual river flows would be under this alternative. The agreement calls for 13 TAF released for the fishery in addition to all other releases from Camanche Reservoir to meet downstream water uses and water use entitlement. Since the completion of Camanche Dam, fish in the Lower Mokelumne have benefitted from flows in excess of 13 TAF, either released for other uses or in excess of the storage capacity.

However, this excess water cannot be relied on in the future. Table 4.6 presents the average flows released under the 1961 agreement since 1967.

4.4.2 CDFG Plan

4.4.2.1 Rationale

Because of their value to sport and commercial fisheries, chinook salmon are the primary focus of fishery management activities on the Mokelumne River under this plan. Since the habitat requirements of steelhead trout are similar to those of chinook, it is presumed that steelhead would also benefit from any improvements to salmon habitat. The intent of the CDFG Plan is to restore, maintain, and protect these species in the Mokelumne River and to significantly increase the natural production of salmon and steelhead trout by the end of this century.

Table 4.5. Required flows for 1961 CDFG agreement (projected operation).

		CAMANCHE			WOODBRIDGE		
		DRY	NORMAL	WET	DRY	NORMAL	WET
OCT	1	63	102		18	18	
	2	63	102		18	18	
NOV	1	108	108		61	61	
	2	108	108		61	61	
DEC	1	126	126		77	77	
	2	126	126		77	77	
JAN	1	100	100		53	53	
	2	100	100		53	53	
FEB	1	89	89		42	42	
	2	89	89		42	42	
MAR	1	94	107		42	42	
	2	94	107		42	42	
APR	1	199	183		13	13	
	2	199	183		13	13	
MAY	1	245	340		24	24	
	2	245	340		24	24	
JUN	1	295	453		31	31	
	2	295	453		31	31	
JUL	1	323	424		37	37	
	2	323	424		37	37	
AUG	1	271	343		28	28	
	2	271	343		28	28	
SEP	1	114	224		20	20	
	2	114	224		20	20	
AVERAGE FLOW (cfs)		169	217		37	37	
TOTAL FLOW (TAF)		122	157		27	27	

Table 4.6. Existing flow conditions under 1961 CDFG agreement (1967-1987 calendar years from USGS gage data).

		CAMANCHE DRY	CAMANCHE NORMAL	CAMANCHE WET	WOODBRIDGE DRY	WOODBRIDGE NORMAL	WOODBRIDGE WET
OCT	1	163	666	1182	104	503	985
	2	163	666	1182	104	503	985
NOV	1	124	421	1162	111	411	1103
	2	124	421	1162	111	411	1103
DEC	1	122	281	1360	95	280	1275
	2	122	281	1360	95	280	1275
JAN	1	107	518	2109	93	513	1987
	2	107	518	2109	93	513	1987
FEB	1	94	524	2345	58	554	2251
	2	94	524	2345	58	554	2251
MAR	1	158	669	2541	55	670	2421
	2	158	669	2541	55	670	2421
APR	1	274	636	2261	40	407	2083
	2	274	636	2261	40	407	2083
MAY	1	355	772	2347	31	406	1801
	2	355	772	2347	31	406	1801
JUN	1	415	869	1745	38	454	1301
	2	415	869	1745	38	454	1301
JUL	1	429	760	1288	39	270	810
	2	429	760	1288	39	270	810
AUG	1	385	698	1048	36	246	567
	2	385	698	1048	36	246	567
SEP	1	278	670	1042	40	354	679
	2	278	670	1042	40	354	679
AVERAGE FLOW(cfs)		242	624	1703	62	422	1439
TOTAL FLOW (TAF)		175	452	1233	45	306	1041

The CDFG Plan has an average annual escapement goal to the Mokelumne River of 15,000 adult chinook salmon and 2,000 adult steelhead spawners. It is hoped that 5,000 salmon would spawn naturally in the river and 10,000 salmon (of which 1,500 are expected to be jacks) and 2,000 steelhead would return to the MRFH. These numbers may be adjusted during wet and dry years to equal, on an average annual basis, a total goal of 15,000 salmon and 2,000 steelhead.

4.4.2.2 Implementation

Flow recommendations for this alternative are presented in Table 4.7 and the flows would be implemented as shown in Table 4.8. The frequency of year types is determined by runoff projections and reflect conditions in the historic record from 1928-1990. CDFG flow recommendations are presumably based on IFIM and other studies conducted by CDFG, which indicate that maximum habitat for spawning occurs at about 300 cfs for chinook salmon and between 300 and 600 cfs for steelhead (CDFG 1991). Maximum rearing habitat for both species occurs at 100 cfs or less. CDFG's flow recommendations are not consistent with their scientific findings, particularly during the rearing period.

During the fall adult migration and spawning period, CDFG recommends flows of around 300 cfs (a little less in dry years, a little more in wet years). In addition, CDFG has specified that additional flow be released to attract salmon into the Mokelumne and facilitate their upstream migration. This additional flow amounts to 20,000 acre-feet in normal and wet years and 10,000 acre-feet in dry years. The attraction flow has been distributed in Table 4.7 in October and early November to maximize the amount of spawning area available in late November and December and maximize evaluation scores.

During the rearing period (March through June), it is assumed that the goal of the CDFG Plan is to optimize rearing habitat. However, CDFG studies indicate that rearing habitat is optimized at 100 cfs or less; therefore, it is not clear how CDFG's flow recommendations are derived from the results of their studies (Table 4.7). This anomaly results in substantially lower habitat evaluation scores for this alternative during the rearing period (see Appendix D).

It is the intent of the CDFG Plan that all naturally-produced salmon and steelhead migrate naturally out of the river and no provision for trapping and trucking out-migrating salmonids is provided. In addition to the rearing-period flows, CDFG recommends that additional flows be used to increase the survival of young chinook salmon and steelhead trout during downstream migration. In normal and wet years, 10 TAF are reserved for this purpose; in dry years, 5 TAF are reserved. CDFG has specified that the results of future studies be used to refine the timing, magnitude, and duration of these releases. These additional flows have been included during the times they would be most effective at controlling water temperature in the lower river for the out-migration of young salmonids (Table 4.7). This maximizes SCIES evaluation scores for the out-migration period.

Table 4.7. Recommended flows for CDFG alternative.

		CAMANCHE						WOODBRIDGE					
		DRY		NORMAL		WET		DRY		NORMAL		WET	
OCT	1	100		474	*	524	*	20	*	474	*	524	*
	2	324	*	524	*	574	*	244	*	624	*	574	*
NOV	1	312	*	524	*	574	*	312	*	524	*	574	*
	2	200		300		350		200		300		350	
DEC	1	200		300		350		200		300		350	
	2	200		300		350		200		300		350	
JAN	1	200		300		350		200		300		350	
	2	200		300		350		200		300		350	
FEB	1	200		300		350		200		300		350	
	2	200		300		350		200		300		350	
MAR	1	200		350		400		200		350		400	
	2	200		350		400		200		350		400	
APR	1	200		400		450		200		400		450	
	2	250		400		450		250		400		450	
MAY	1	384	@	450		450		384	@	450		450	
	2	384	@	562	@	450		384	@	562	@	450	
JUN	1	200		512	@	468	@	20		512	@	468	@
	2	200		512	@	468	@	20		512	@	468	@
JUL	1	200		150		300		20		150		300	
	2	200		150		300		20		150		300	
AUG	1	200		100		300		20		100		300	
	2	200		100		300		20		100		300	
SEP	1	200		100		300		20		100		300	
	2	200		100		300		20		100		300	
AVERAGE FLOW (cfs)		223		327		394		156		332		394	
TOTAL FLOW (TAF)		162		237		285		113		240		285	

* Includes attraction flow allocated by BioSystems to maximize SCIES scores.
@ Includes out-migration flow allocated by BioSystems to maximize SCIES scores.

Table 4.8. Implementation flows for CDFG alternative.

		CAMANCHE DRY		CAMANCHE NORMAL		CAMANCHE WET		WOODBRIDGE DRY		WOODBRIDGE NORMAL		WOODBRIDGE WET	
OCT	1	128		615	*	665	*	45	*	474	*	524	*
	2	352	*	765	*	715	*	269	*	624	*	574	*
NOV	1	369	*	581	*	631	*	312	*	524	*	574	*
	2	257		357		407		200		300		350	
DEC	1	274		374		424		200		300		350	
	2	274		374		424		200		300		350	
JAN	1	267		367		417		200		300		350	
	2	267		367		417		200		300		350	
FEB	1	260		360		410		200		300		350	
	2	260		360		410		200		300		350	
MAR	1	282		433		483		200		350		400	
	2	282		433		483		200		350		400	
APR	1	346		544		594		200		400		450	
	2	396		544		594		250		400		450	
MAY	1	596	@	749		749		384	@	450		450	
	2	596	@	861	@	749		384	@	562	@	450	
JUN	1	286		915	@	871	@	20		512	@	468	@
	2	286		915	@	871	@	20		512	@	468	@
JUL	1	297		599		749		20		150		300	
	2	297		599		749		20		150		300	
AUG	1	259		478		678		22		100		300	
	2	259		478		678		22		100		300	
SEP	1	241		345		545		77		100		300	
	2	241		345		545		77		100		300	
AVERAGE FLOW(cfs)		307		532		594		163		332		394	
TOTAL FLOW (TAF)		222		385		430		118		240		285	

* Includes attraction flow allocated by BioSystems to maximize SCIES scores. Allocation of attraction flows was not specified by CDFG.

@ Includes outmigration flow allocated by BioSystems to maximize SCIES scores.

The CDFG's goal for the MRFH is to produce 1.5 million chinook salmon yearlings (or their equivalent) from 10,000 adult chinook salmon and to produce 100,000 steelhead yearlings (or their equivalent) from 2,000 adult steelhead. All MRFH production (except 2 million salmon stamp enhancement fish) is to be released to the Mokelumne River. To meet these production levels, and because yearlings would need to be held through the summer, the MRFH would need to be substantially expanded and upgraded. To meet CDFG's river versus hatchery goals, approximately two-thirds of the escapement would have to enter the hatchery; however, CDFG studies indicate that less than 25 percent of the total escapement actually enters the MRFH on average.

4.4.2.3 Evaluation

The CDFG goal of 15,000 adult chinook salmon spawners is equal to the largest run ever estimated in the Mokelumne River, greater than the largest run ever counted in the Mokelumne River (12,000), and about five times greater than the average historic run (3,000 fish from 1940-1990). The goal of 2,000 adult steelhead is about 75 times greater than the average number of steelhead returning to the hatchery between 1964 and 1990. These goals may be unrealistically high (Appendix A).

The habitat analysis (Table 4.9) indicates that most of the time the CDFG plan conditions would be good for each life stage of chinook salmon (SCIES scores of 60 or better). The lowest values would occur during the rearing period in normal and wet years because of high flows. High flow is needed in this reach to meet downstream needs (irrigation supply plus flows below Woodbridge Dam). A low value also occurs in dry years during out-migration below Woodbridge Dam because of low flow and related high water temperatures. Conditions for spawning and out-migration in Camanche reach would be better in normal and wet year flows than in dry years; however, fry and juvenile rearing would be optimized at lower flows (100 cfs), which occur during dry years. It is probably better to enhance out-migration at the expense of rearing habitat. High temperatures at low out-migration flow can become lethal, whereas high flow during rearing may not be — fish can always move to areas with less current.

Table 4.9. SCIES average scores by species and lifestage for CDFG alternative.

SPECIES/REACH	LIFESTAGE	CRITICAL DRY	DRY	NORMAL	WET
Chinook Salmon					
Camanche Reach	In-migration		100	100	100
	Spawning		87	94	94
	Fry		64	45	39
	Juvenile		65	37	35
	Out-migration		94	100	100
Woodbridge Reach	In-migration		99	100	100
	Out-migration		48	84	83
Combined Reaches Scores			78	84	83
Steelhead Trout					
Camanche Reach	In-migration		100	100	100
	Spawning		92	90	89
	Fry		52	37	32
	Juvenile		67	46	36
	Out-migration		100	100	100
Woodbridge Reach	In-migration		100	100	100
	Out-migration		99	100	100
Combined Reaches Scores			91	87	86

Habitat value for steelhead would be generally high (Table 4.9). The lowest scores occur during the fry and juvenile rearing periods, particularly in normal and wet year types due to higher than optimum flow. Out-migration scores are good in both reaches because steelhead usually out-migrate at times when temperature is not a problem (i.e., during the winter).

The life cycle model (Table 4.10, Figure 4-3, and Appendix E) uses year type frequencies from the historic runoff record for 1920-1990. The Lake Lodi mortality rates, based on WID diversion rates, should be 46 percent under CDFG dry year flows and possibly as low as 26-27 percent in normal and wet years (Appendix Table E.2). No salmon would be trapped and trucked under the CDFG Plan. Estimated migrant losses between Woodbridge Dam and the Delta are based on water temperature criteria in the lower river and the portion of the total out-migration exposed to those water temperatures (i.e., 1% in March and April, 48% in May, 46% in June, and 4% in July) (Section 3.0). The MRFH would produce 2 million smolts for release below the Delta and 1,500,000 yearling salmon for release in the river below Camanche Dam, as specified in the CDFG Management Plan (CDFG 1991). This level of hatchery production would require about 4 million eggs or fry be imported from other sources, assuming a return of 1,150 Mokelumne River fish to the hatchery from a total expected run of 5,000 (23%).

The CDFG Plan has the highest predicted return to the Mokelumne River of all alternatives because of the large number of hatchery yearlings released below Camanche Dam. The CDFG Plan also has maximum natural smolt production (568,000 predicted at the mouth of the Mokelumne) (Table 4.10). Total smolt production, harvest, and system escapement are about average. Out-migration flows in these alternatives would tend to reduce losses in Lake Lodi since the diversion percentage is minimized and would provide suitable temperatures between Lake Lodi and the Delta (especially in normal and wet years).

On average, from an initial run of 5,000 salmon, slightly more than 13,000 salmon would be predicted to return to the Mokelumne. This indicates a population expanded beyond historical levels (3,000) and saturated spawning habitat. Although available data indicate that this program should work, it should be regarded as experimental because changing conditions in the Delta and ocean could influence its success, and a yearling program of this magnitude has never been tried on the Mokelumne or elsewhere in California. In addition, stocking 1.5 million yearlings may result in long-term impacts on the population dynamics of the run such as age and size at return, maturity rates, fecundity, and out-migration patterns.

In addition to making flow recommendations, the CDFG Plan presents water temperature criteria to be met at different times and locations, depending on the life stage present (Table 4.4). BioSystems' temperature modeling (see Appendix C) indicates that CDFG temperature criteria cannot always be met at the flow levels recommended by CDFG, and the criteria provided is sometimes more stringent than research indicates is necessary for the particular life history stage (Appendix A).

Table 4.10. CDFG alternative life cycle model output (see Appendix E for more detail).

Rates in the top part of Table are used to calculate numbers in lower part of table. Equations for each calculation are given to the right of the appropriate row.

ROW	SURVIVAL RATES	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR
1	YEAR TYPE FREQUENCY OF OCCURENCE	0%	14%	47%	39%
2	FEMALES IN RUN	35%	35%	35%	35%
3	NUMBER OF EGGS PER FEMALE	4600	4600	4600	4600
4	EGG TO FRY SURVIVAL	25%	25%	25%	25%
5	FRY TO SMOLT SURVIVAL	68%	68%	68%	68%
6	OUTMIGRANT SURVIVAL TO L. LODI	95%	95%	95%	95%
7	SURVIVAL THROUGH L. LODI	0%	54%	73%	74%
8	OUTMIGRANTS TRAPPED AND TRUCKED	0%	0%	0%	0%
9	OUTMIGRANT SURVIVAL FROM WOODBRIDGE TO DELTA	0%	48%	84%	83%
10	OUTMIGRANT SURVIVAL THROUGH DELTA	15%	15%	15%	15%
11	SURVIVAL OF SMOLTS RELEASED IN DELTA	80%	80%	80%	80%
12	SURVIVAL OF YEARLINGS RELEASED IN DELTA	90%	90%	90%	90%
13	SURVIVAL OF YEARLINGS RELEASED AT MRFH	45%	45%	45%	45%
14	OCEAN SURVIVAL OF SMOLTS	3%	3%	3%	3%
15	OCEAN SURVIVAL OF YEARLINGS	6%	6%	6%	6%
16	SURVIVING HARVEST	34%	34%	34%	34%
17	NATURAL OUTMIGRANT STRAYING RATE	15%	15%	15%	15%
18	DELTA RELEASE STRAYING RATE	95%	95%	95%	95%

ROW	NUMBERS OF FISH	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR	WEIGHTED AVERAGE	
19	INITIAL TOTAL NUMBER OF SPAWNERS	0	5000	5000	5000	5000	
	HATCHERY						
20	NUMBER OF SPAWNERS ENTERING HATCHERY	0	1150	1150	1150	1150	
21	EGGS FROM FISH RETURNING TO HATCHERY	0	1851500	1851500	1851500	1851500	
22	TOTAL HATCHERY EGGS NEEDED	0	5833333	5833333	5833333	5833333	
23	EGGS OR FRY IMPORTED FROM OTHER HATCHERY	0	3981833	3981833	3981833	3981833	
24	NUMBER OF SMOLTS RELEASED AT MRFH	0	0	0	0	0	
25	NUMBER OF SMOLTS RELEASED IN DELTA	0	2000000	2000000	2000000	2000000	
26	NUMBER OF YEARLINGS RELEASED AT MRFH	0	1500000	1500000	1500000	1500000	
27	NUMBER OF YEARLINGS RELEASED IN DELTA	0	0	0	0	0	
	RIVER						
28	NUMBER SPAWNING NATURALLY IN RIVER	0	3850	3850	3850	3850	
29	EGGS DEPOSITED IN RIVER	0	6198500	6198500	6198500	6198500	
30	FRY HATCHING IN RIVER	0	1549625	1549625	1549625	1549625	
31	NATURAL SMOLTS ENTERING LAKE LODI	0	1006946	1006946	1006946	1006946	
32	TOTAL SMOLTS ENTERING LAKE LODI	0	1006946	1006946	1006946	1006946	
33	SMOLTS SURVIVING LAKE LODI	0	543751	735071	745140	712213	
34	NUMBER OF SMOLTS TRAPPED AND TRUCKED	0	0	0	0	0	
35	SMOLTS MIGRATING NATURALLY TO DELTA	0	261000	617459	618466	567948	
36	NATURALLY PRODUCED SMOLTS TO DELTA	0	261000	617459	618466	567948	
37	SMOLTS MIGRATING NATURALLY TO CHIPPS ISLAND	0	39150	92619	92770	85192	
38	SMOLTS TRUCKED TO CHIPPS ISLAND	0	1600000	1600000	1600000	1600000	
39	TOTAL SMOLTS TO CHIPPS ISLAND	0	1639150	1692619	1692770	1685192	
40	YEARLINGS TO CHIPPS ISLAND	0	675000	675000	675000	675000	
41	NUMBER SURVIVING TO BE HARVESTED OR SPAWN	0	89675	91279	91283	91056	
42	NUMBER HARVESTED	0	59185	60244	60247	60097	
43	TOTAL NUMBER LEFT TO SPAWN	0	30489	31035	31036	30959	
44	NUMBER STRAYING TO OTHER RIVERS	0	17629	17711	17711	17700	
45	NUMBER RETURNING TO MOKELUMNE	0	12860	13324	13325	13259	
	NATURAL SMOLTS RETURNING	0	339	803	804	739	6%
	TRUCKED SMOLTS RETURNING	0	816	816	816	816	6%
	RIVER YEARLINGS RETURNING	0	11704	11704	11704	11704	88%
	DELTA YEARLINGS RETURNING	0	0	0	0	0	0%
		0	12860	13324	13325	13259	

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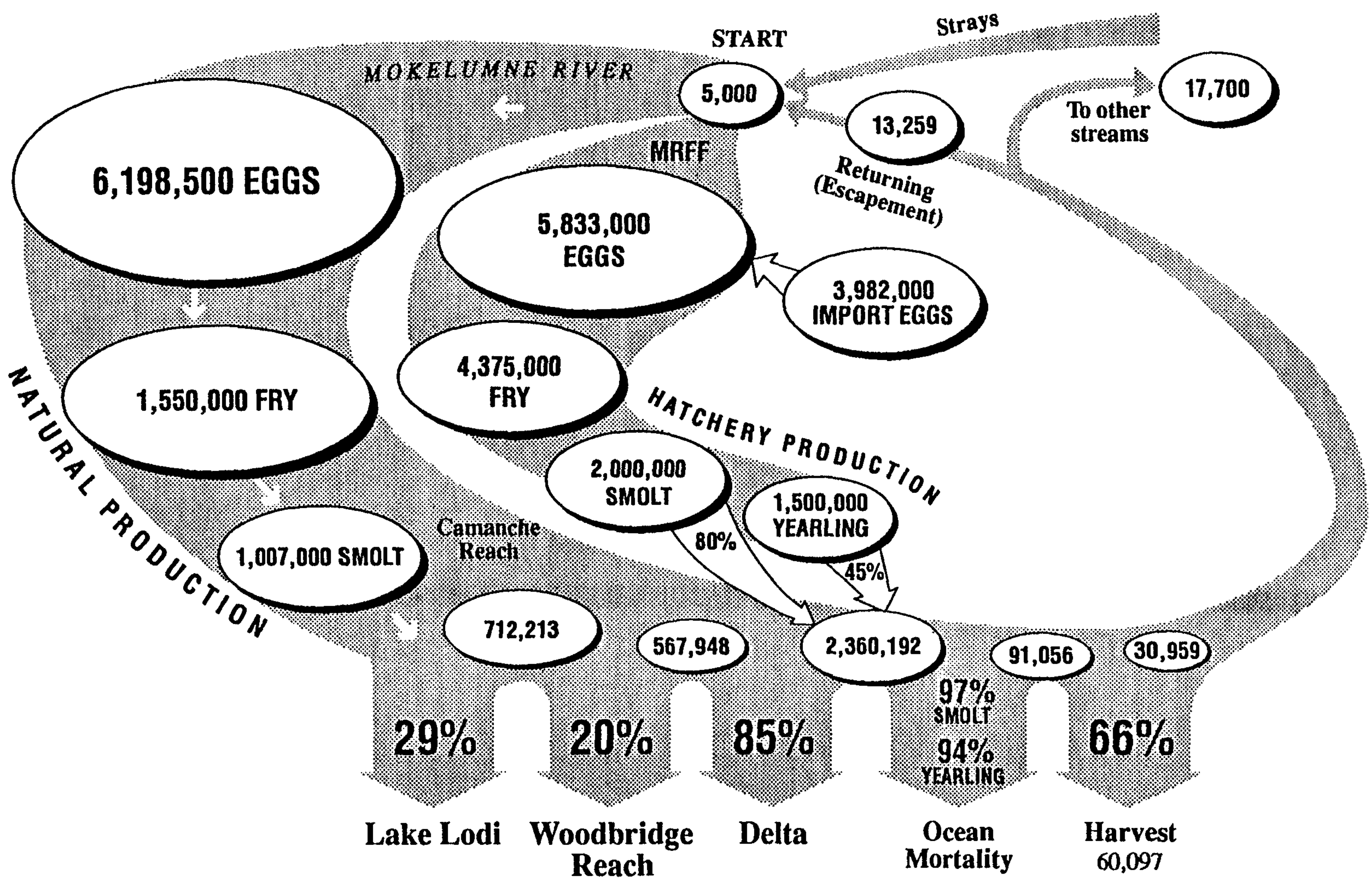

Figure 4-3. CDFG alternative life cycle model.

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4.4.3 Escapement-Oriented Alternative

4.4.3.1 Rationale

Under existing hatchery management practices and conditions in the Lower Mokelumne River and Delta, the size of the Mokelumne salmon run is most strongly correlated to flow in the Mokelumne and Delta during the fall migration season (Section 3.2.2.2). This alternative is designed to achieve returns of about 5,000 salmon to the Mokelumne River by providing significant fall attraction flows. Since the Mokelumne run has averaged about 2,800 fish, this would meet the state goal of doubling chinook salmon runs and provide sufficient winter flow for steelhead migration.

4.4.3.2 Implementation

Flow recommendations for this alternative are provided in Table 4.11; flows would actually be implemented as shown in Table 4.12. Unlike the CDFG Plan, the frequency of year types is determined by using a combination of runoff and reservoir storage projections (see above). This results in a different frequency of year types than a system based on runoff alone. Projections based on EBMUDSIM modeling indicate that wet/normal years would occur 52 percent of the time, dry years 27 percent, and critical dry years 20 percent.

This alternative attempts to provide optimum conditions for salmon and steelhead spawning, rearing, and emigration by balancing water temperature constraints and weighted usable habitat area (based on CDFG 1991 studies). These criteria are relaxed in dry years to less than optimum levels and to minimum levels for maintenance of the fishery in critical dry years.

During the smolt migration period, sufficient flow would be provided to maintain suitable water temperature conditions through June in normal and wet years, and through the end of May in dry years to conserve water. Smolts would be trapped above Lake Lodi and trucked to release points below the Delta after 1 June in dry years, and after 30 June in normal and wet years. In critical dry years, all migrants would be trapped and trucked from April through July.

This alternative assumes CDFG hatchery management practices in the Central Valley will remain consistent with past practices. Therefore, under this alternative, MRFH operations would remain at or near existing levels, producing 1.27 million salmon smolts, 530,000 salmon yearlings, and 70,000 steelhead yearlings (based on production from 1980 to 1989). All salmon would be planted below the Delta to maximize returns to the ocean fishery, and steelhead would be planted as catchable trout at various locations, including the Lower Mokelumne River.

Table 4.11. Recommended flows for escapement-oriented alternative.

		CAMANCHE CRITICAL		CAMANCHE DRY		CAMANCHE NORMAL		CAMANCHE WET		WOODBRIDGE CRITICAL		WOODBRIDGE DRY		WOODBRIDGE NORMAL		WOODBRIDGE WET	
OCT	1	100		100		100		100		20		20		20		20	
	2	100		200		300		300		50		300	$	300	$	300	$
NOV	1	100		600		600		600		200		600		600		600	
	2	100		600		600		600		200		600		600		600	
DEC	1	100		600		600		600		200		550		550		550	
	2	100		200		300		300		50	**	100	**	100	**	200	**
JAN	1	100		200		300		300		50	**	100	**	100	**	200	**
	2	100		200		300		300		50	**	100	**	100	**	200	**
FEB	1	100		200		200		200		50	**	100	**	100	**	200	**
	2	100		200		200		200		50	**	100	**	100	**	200	**
MAR	1	100		200		200		200		50	**	100	**	100	**	200	**
	2	100		200		200		200		50	**	100	**	100	**	200	**
APR	1	100		100		100		100		20	@	100		100		100	
	2	100		100		100		100		20	@	150		150		150	
MAY	1	100		100		100		100		20	@	300		300		300	
	2	100		100		100		100		20	@	400		400		400	
JUN	1	300		300		300		300		20	@	20	@	500		500	
	2	300		300		300		300		20	@	20	@	500	#	500	#
JUL	1	100	*	200	*	450		450		20	@	20	@	20	@	20	@
	2	100	*	200	*	200	*	200	*	20	@	20	@	20	@	20	@
AUG	1	100	*	200	*	200	*	200	*	20		20		20		20	
	2	100	*	200	*	200	*	200	*	20		20		20		20	
SEP	1	100	*	100	*	100	*	100	*	20		20		20		20	
	2	100	*	100	*	100	*	100	*	20		20		20		20	
AVERAGE FLOW (cfs)		117		229		256		256		53		162		202		231	
TOTAL FLOW (TAF)		84		166		186		186		38		117		146		167	

* Additional flows for steelhead
** Migration flows for steelhead unknown
$ This release should only be made if Camanche release temperature is 15.5 degrees C or less.
# This release should only be made when conditions in the Delta are conducive to smolt survival, otherwise release 20 cfs below Woodbridge and trap out-migrants.
@ Trap and truck

Table 4.12. Implementation flows for escapement-oriented alternative.

		CAMANCHE CRITICAL		CAMANCHE DRY		CAMANCHE NORMAL		CAMANCHE WET		WOODBRIDGE CRITICAL		WOODBRIDGE DRY		WOODBRIDGE NORMAL		WOODBRIDGE WET	
OCT	1	103		103		161		161		20		20		20		20	
	2	133		383		441		441		50		300	$	300	$	300	$
NOV	1	257		657		657		657		200		600		600		600	
	2	257		657		657		657		200		600		600		600	
DEC	1	274		624		624		624		200		550		550		550	
	2	124		200		300		300		50	**	126	**	226	**	226	**
JAN	1	117		200		300		300		50	**	133	**	233	**	233	**
	2	117		200		300		300		50	**	133	**	233	**	233	**
FEB	1	110		200		200		260		50	**	140	**	140	**	200	**
	2	110		200		200		260		50	**	140	**	140	**	200	**
MAR	1	132		200		200		283		50	**	118	**	117	**	200	**
	2	132		200		200		283		50	**	118	**	117	**	200	**
APR	1	166		246		244		244		20	@	100		100		100	
	2	166		296		294		294		20	@	150		150		150	
MAY	1	232		512		599		599		20	@	300		300		300	
	2	232		612		699		699		20	@	400		400		400	
JUN	1	300		300		903		903		34	@	34	@	500		500	
	2	300		300		903		903		34	@	34	@	500	#	500	#
JUL	1	297	*	297	*	469		469		20	@	20	@	20	@	20	@
	2	297	*	297	*	469	*	469	*	20	@	20	@	20	@	20	@
AUG	1	257	*	257	*	398	*	398	*	20		20		20		20	
	2	257	*	257	*	398	*	398	*	20		20		20		20	
SEP	1	184	*	184	*	265	*	265	*	20		20		20		20	
	2	184	*	184	*	265	*	265	*	20		20		20		20	
AVERAGE FLOW (cfs)		197		315		423		435		54		172		223		235	
TOTAL FLOW (TAF)		143		228		306		315		39		124		161		170	

* Additional flows for steelhead

** Migration flows for steelhead unknown

$ This release should only be made if Camanche release temperature is 15.5 degrees C or less.

This release should only be made when conditions in the Delta are conducive to smolt survival, otherwise release 20 cfs below Woodbridge and trap out-migrants.

@ Trap and truck

4.4.3.3 Evaluation

Although this is the most likely alternative to succeed in increasing the Mokelumne run under existing management practices and environmental conditions (including Delta conditions), it does not represent the best long-term management strategy because it relies on attracting stray salmon into the river through large releases of flow. It also could attract more salmon than the available habitat can support. Other strategies could support equal or greater spawning runs with lower flows (i.e., production/natural). In addition, this alternative assumes that current CDFG fishery management practices will continue, but CDFG is modifying its objectives on many Central Valley streams, including the Mokelumne, and is likely to revise some of these practices.

The habitat analysis (Table 4.13) indicates that conditions would be fairly good for each life stage of chinook salmon most of the time (SCIES scores of 60 or more). The lowest value occurs during the out-migration period because of low flows downstream of Woodbridge in dry and critical dry years, which would increase water temperature. Higher flows in normal and wet years in the Camanche reach would create better spawning and out-migration conditions than in dry years, but fry and juvenile rearing would be optimized at lower flows (100 cfs), which would occur during dry years. The minimum habitat value would occur during the out-migration period below Woodbridge. Out-migrating salmon would be trapped above Lake Lodi and trucked below the Delta at these times.

Table 4.13. SCIES average scores by species and lifestage for escapement alternative.

SPECIES/REACH	LIFESTAGE	CRITICAL DRY	DRY	NORMAL	WET
Chinook Salmon					
Camanche Reach	In-migration	100	100	100	100
	Spawning	69	81	88	88
	Fry	99	75	72	64
	Juvenile	86	70	55	55
	Out-migration	99	99	100	100
Woodbridge Reach	In-migration	97	99	100	100
	Out-migration	20	45	83	83
Combined Reaches Scores		75	79	87	86
Steelhead Trout					
Camanche Reach	In-migration	100	100	100	100
	Spawning	64	93	92	91
	Fry	90	56	54	53
	Juvenile	79	67	56	55
	Out-migration	100	100	100	100
Woodbridge Reach	In-migration	100	100	100	100
	Out-migration	95	98	100	100
Combined Reaches Scores		92	91	90	90

Habitat conditions for steelhead would also be good at most times. The lowest values are for spawning in critical dry years (64% of optimum) and for rearing in other year types (53% to 67% of optimum).

The life cycle for this alternative, depicted in Figure 4-4, uses a weighted average of the four year types. Supporting assumptions and calculations are provided in Table 4.14 and Appendix E.

The frequency of year types is determined by using a combination of runoff projections and system storage and was determined by EBMUDSIM model results for 1921-1990. As in each of the other alternatives, an initial run of 5,000 salmon is split into those returning to the hatchery (1,150) and those spawning naturally in the river (3,850). This alternative would require 3.2 million eggs to meet production goals. Because Mokelumne returns would produce only 1.85 million eggs, 1.3 million of those needed would have to be imported as eggs or fry from other hatcheries. Imported eggs and fry would not have to be separated from those obtained from fish returning to the Mokelumne under this alternative.

This alternative assumes existing levels of production and current hatchery management practices. Under that assumption, about 1,370,000 smolts and 530,000 yearlings would be released each year below the Delta. Smolts would be released in early summer and yearlings would be released in the fall.

During critically dry years, natural spawning in the river would yield about 1 million smolts, but due to poor survival conditions in Lake Lodi, only 32 percent of these (based on percentage diverted [Appendix E]), or about 340,000, would reach the trap at Woodbridge Dam. All natural smolt production would be trucked to a release point below the Delta in critical dry years. According to model predictions, the total number of smolts reaching Chipps Island (including those transported from the hatchery and from Lake Lodi) would be approximately 1.35 million in critical dry years.

In dry years, the greater bypass flows would allow more smolts to survive in Lake Lodi (49%—based on percentage diverted), and thus natural out-migrants would not be trapped and trucked until after 1 June, allowing about half of the natural production to migrate naturally through the lower river. The total number of smolts produced would be around 1.3 million (predicted at Chipps Island). Harvest and system escapement would remain comparable to critically dry years, but returns to the Mokelumne would be somewhat higher due to the larger number of naturally out-migrating smolts (Table 4.14).

In normal and wet years, river conditions would be good through the end of June and the out-migrant survival rate through Lake Lodi would be relatively high (70%—based on percentage diverted). Trapping and trucking would be conducted only after the end of June. These conditions would result in slightly lower overall smolt production, harvest, and system escapement. However, returns to the Mokelumne would be greater because more fish would

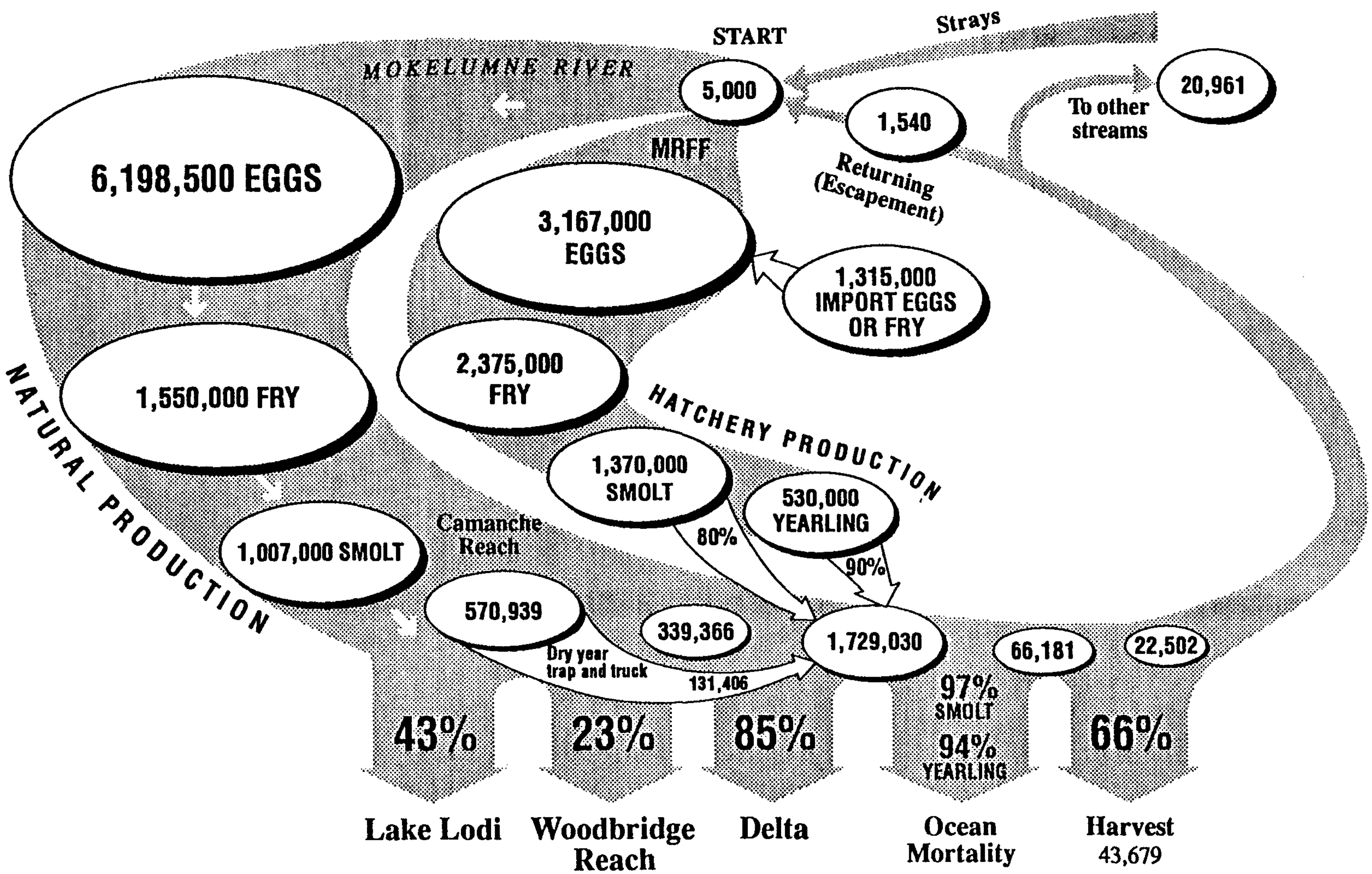

Figure 4-4. Escapement-oriented alternative life cycle model.

Table 4.14. Escapement-oriented alternative life cycle model output (see Appendix E for more detail).

Rates in the top part of Table are used to calculate numbers in lower part of table. Equations for each calculation are given to the right of the appropriate row.

ROW	SURVIVAL RATES	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR
1	YEAR TYPE FREQUENCY OF OCCURENCE	20%	27%	11%	41%
2	FEMALES IN RUN	35%	35%	35%	35%
3	NUMBER OF EGGS PER FEMALE	4600	4600	4600	4600
4	EGG TO FRY SURVIVAL	25%	25%	25%	25%
5	FRY TO SMOLT SURVIVAL	68%	68%	68%	68%
6	OUTMIGRANT SURVIVAL TO L. LODI	95%	95%	95%	95%
7	SURVIVAL THROUGH L. LODI	32%	49%	70%	70%
8	OUTMIGRANTS TRAPPED AND TRUCKED	100%	50%	0%	0%
9	OUTMIGRANT SURVIVAL FROM WOODBRIDGE TO DELTA	20%	45%	83%	83%
10	OUTMIGRANT SURVIVAL THROUGH DELTA	0.15	0.15	0.15	0.15
11	SURVIVAL OF SMOLTS RELEASED IN DELTA	0.8	0.8	0.8	0.8
12	SURVIVAL OF YEARLINGS RELEASED IN DELTA	0.9	0.9	0.9	0.9
13	SURVIVAL OF YEARLINGS RELEASED AT MRFH	0.45	0.45	0.45	0.45
14	OCEAN SURVIVAL OF SMOLTS	0.03	0.03	0.03	0.03
15	OCEAN SURVIVAL OF YEARLINGS	0.06	0.06	0.06	0.06
16	SURVIVING HARVEST	0.34	0.34	0.34	0.34
17	NATURAL OUTMIGRANT STRAYING RATE	0.15	0.15	0.15	0.15
18	DELTA RELEASE STRAYING RATE	0.95	0.95	0.95	0.95

ROW	NUMBERS OF FISH	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR	WEIGHTED AVERAGE	
19	INITIAL TOTAL NUMBER OF SPAWNERS	5000	5000	5000	5000	5000	
20	NUMBER OF SPAWNERS ENTERING HATCHERY	1150	1150	1150	1150	1150	
21	EGGS FROM FISH RETURNING TO HATCHERY	1851500	1851500	1851500	1851500	1851500	
22	TOTAL HATCHERY EGGS NEEDED	3166667	3166667	3166667	3166667	3166667	
23	EGGS OR FRY IMPORTED FROM OTHER HATCHERY	1315167	1315167	1315167	1315167	1315167	
24	NUMBER OF SMOLTS RELEASED AT MRFH	0	0	0	0	0	
25	NUMBER OF SMOLTS RELEASED IN DELTA	1370000	1370000	1370000	1370000	1370000	
26	NUMBER OF YEARLINGS RELEASED AT MRFH	0	0	0	0	0	
27	NUMBER OF YEARLINGS RELEASED IN DELTA	530000	530000	530000	530000	530000	
28	NUMBER SPAWNING NATURALLY IN RIVER	3850	3850	3850	3850	3850	
29	EGGS DEPOSITED IN RIVER	6198500	6198500	6198500	6198500	6198500	
30	FRY HATCHING IN RIVER	1549625	1549625	1549625	1549625	1549625	
31	NATURAL SMOLTS ENTERING LAKE LODI	1006946	1006946	1006946	1006946	1006946	
32	TOTAL SMOLTS ENTERING LAKE LODI	1006946	1006946	1006946	1006946	1006946	
33	SMOLTS SURVIVING LAKE LODI	322223	493404	704862	704862	570939	
34	NUMBER OF SMOLTS TRAPPED AND TRUCKED	322223	246702	0	0	131406	
35	SMOLTS MIGRATING NATURALLY TO DELTA	0	111016	585036	585036	339366	
36	NATURALLY PRODUCED SMOLTS TO DELTA	0	111016	585036	585036	339366	
37	SMOLTS MIGRATING NATURALLY TO CHIPPS ISLAND	0	16652	87755	87755	50905	
38	SMOLTS TRUCKED TO CHIPPS ISLAND	1353778	1293361	1096000	1096000	1201125	
39	TOTAL SMOLTS TO CHIPPS ISLAND	1353778	1310014	1183755	1183755	1252030	
40	YEARLINGS TO CHIPPS ISLAND	477000	477000	477000	477000	477000	
41	NUMBER SURVIVING TO BE HARVESTED OR SPAWN	69233	67920	64133	64133	66181	
42	NUMBER HARVESTED	45694	44827	42328	42328	43679	
43	TOTAL NUMBER LEFT TO SPAWN	23539	23093	21805	21805	22502	
44	NUMBER STRAYING TO OTHER RIVERS	22362	21802	19999	19999	20961	
45	NUMBER RETURNING TO MOKELUMNE	1177	1291	1806	1806	1540	
	NATURAL SMOLTS RETURNING	0	144	761	761	441	29%
	TRUCKED SMOLTS RETURNING	690	660	559	559	613	40%
	RIVER YEARLINGS RETURNING	0	0	0	0	0	0%
	DELTA YEARLINGS RETURNING	486.54	487	487	487	487	32%
		1177	1291	1806	1806	1540	

migrate naturally out of the Mokelumne and their straying rate is estimated to be lower (about 15%) (Section 3.0).

Under the escapement alternative, combined smolt and yearling production, harvest, total escapement (strays are not accounted for in the life cycle model), and returns to the Mokelumne River are the lowest of all the alternatives. The amount of naturally-produced smolts would be fairly high (approximately 340,000, estimated at the mouth of the Mokelumne) because out-migration flows would reduce losses in Lake Lodi and maintain suitable temperatures between Lake Lodi and the Delta. Under this alternative, naturally out-migrating smolts would account for 30 percent of the Mokelumne returns, trucked smolts would account for 68 percent, and yearlings only about 2 percent (life cycle model results).

The predicted average return of about 1,500 salmon would not balance the initial average run of 5,000. While these numbers indicate a declining population, this alternative proposes to augment the return of Mokelumne-origin fish with strays from other systems that would be attracted by high fall flows. Although this practice would meet long-term escapement goals, it would do so at a high cost in water. In addition, there are benefits in terms of genetic diversity that result from distinct stocks in different rivers. This alternative would result in continued mixing of stocks and the further loss of genetic integrity. Finally, pre-spawning adults may be exposed to elevated temperatures, which would decrease the viability of their eggs.

4.4.4 Production-Oriented Alternative, Natural Emphasis

4.4.4.1 Rationale

In contrast to the escapement-oriented alternative, the production-oriented alternative measures its success in terms of salmon and steelhead production within the Mokelumne River, rather than escapement to it. However, improved production would also improve future escapement. The problem with managing for escapement is that it is influenced by many factors external to the river. These include conditions in the Delta that impair the migration success of juveniles and adult spawners, as well as ocean survival conditions such as the sport and commercial harvest. Because Delta and ocean conditions are beyond the control of EBMUD, the river management program's success should be measured by the number of smolts produced. However, Mokelumne River salmon production can also be managed to maximize returns of Mokelumne-produced fish to the Mokelumne and minimize straying to other rivers.

This alternative also responds to the CDFG goal of emphasizing natural in-river production over hatchery production. The hatchery and river would be managed together to increase the return rate of salmon produced in the Mokelumne River.

The hatchery program will rebuild the natural spawning population as well as the portion of the run returning to the hatchery as adult spawners. A larger hatchery run will provide the hatchery manager with the opportunity to collect broodstock throughout the entire salmon

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spawning run to increase genetic fitness and diversity. With a larger number of salmon and steelhead to select for broodstock, the hatchery program can focus on selecting for specific traits in the hatchery to improve the quality of the Mokelumne salmon and steelhead run.

The Quinault National Fish Hatchery in the State of Washington is one example where a hatchery program was used to improve the quality of the stock by dramatically increasing the size at adult return. By carefully selecting hatchery broodstock, the hatchery was able to increase the number of larger steelhead in the spawning run by selecting broodstock that returned as four-year-old fish instead of as three-year-old spawners.

4.4.4.2 Implementation

The flow recommendations for this alternative are presented in Table 4.15. The flows that would be implemented are shown in Table 4.16. While the escapement-oriented alternative assumes high fall flows will attract stray fish into the river (Section 3.0), the production-oriented strategy is based on the premise that salmon produced in the Mokelumne will return if a lower but consistent fall flow is provided for upstream migration and spawning. Although migration flows needed for steelhead are uncertain, this alternative also provides a level of flow that would allow for steelhead migration (50 cfs in critical dry years and 100 cfs in other years from December through March).

Under this alternative, river flow would be managed to provide river habitat conditions that maximize the number of naturally-produced smolts. Optimum conditions for salmon and steelhead spawning, rearing, and out-migration would be provided by balancing water temperature constraints and weighted usable habitat area (based on CDFG 1991 studies). These criteria would be relaxed to less than optimum conditions in dry years and to minimum levels for maintenance in critical dry years (which would not occur more than 16% of the time).

During the smolt migration period, sufficient flow would be provided to meet water temperature criteria through the end of June in normal and wet years and through the end of May in dry years. Smolts would be trapped above Lake Lodi and trucked to release points below the Delta after 1 June in dry years, and after 30 June in normal and wet years. In critical dry years, all migrants would be trapped and trucked from April through July.

The MRFH would be operated to maximize returns of Mokelumne River fish by taking eggs from salmon returning to the Mokelumne River and returning them to the Mokelumne as smolts and yearlings. Of these, 800,000 would be reared to yearlings and planted in the Mokelumne River, and the remaining eggs would be reared to smolts and released in the Mokelumne under conditions most favorable for their survival (i.e., before the water temperature is too warm). Eggs imported from other hatcheries would be reared separately and planted as smolts in the Delta to enhance ocean harvest and returns to other parts of the Central Valley.

Table 4.15. Recommended flows for production-oriented alternative (natural emphasis).

		CAMANCHE CRITICAL		CAMANCHE DRY		CAMANCHE NORMAL		CAMANCHE WET		WOODBRIDGE CRITICAL		WOODBRIDGE DRY		WOODBRIDGE NORMAL		WOODBRIDGE WET	
OCT	1	100	*	100	*	100	*	100	*	20		20		20		20	
	2	100	*	200	*	300		300		20		100	$	200	$	200	$
NOV	1	100		200		300		300		100		200		300		300	
	2	100		200		300		300		100		200		300		300	
DEC	1	100		200		300		300		100		200		300		300	
	2	100		200		300		300		50	*	100	*	100	*	100	*
JAN	1	100		200		200		200		50	*	100	*	100	*	100	*
	2	100		200		200		200		50	*	100	*	100	*	100	*
FEB	1	100		200		200		200		50	*	100	*	100	*	100	*
	2	100		200		200		200		50	*	100	*	100	*	100	*
MAR	1	100		200		200		200		50	*	100	*	100	*	100	*
	2	100		200		200		200		50	*	100	*	100	*	100	*
APR	1	100		100		100		100		20	@	100		100		100	
	2	100		100		100		100		20	@	150		150		150	
MAY	1	100		100		100		100		20	@	300		300		300	
	2	100		100		100		100		20	@	400		400		400	
JUN	1	300		300		300		300		20	@	20	@	500		500	
	2	300		300		300		300		20	@	20	@	500	#	500	#
JUL	1	100	**	200	**	450		450		20	@	20	@	20	@	20	@
	2	100	**	200	**	200	**	200	**	20	@	20	@	20	@	20	@
AUG	1	100	**	200	**	200	**	200	**	20		20		20		20	
	2	100	**	200	**	200	**	200	**	20		20		20		20	
SEP	1	100	**	100	**	100	**	100	**	20		20		20		20	
	2	100	**	100	**	100	**	100	**	20		20		20		20	
AVERAGE FLOW (cfs)		117		179		210		210		39		105		162		162	
TOTAL FLOW (TAF)		84		130		152		152		28		76		117		117	

* Flow for steelhead, no flow requirement for chinook salmon
@ Trap and truck
$ This release should only be made if Camanche release temperature is 15.5 degrees C or less.
# This release should only be made when conditions in the Delta are conducive to smolt survival, otherwise release 20 cfs below Woodbridge and trap out-migrants.

Table 4.16. Implementation flows for production-oriented alternative (natural emphasis).

		CAMANCHE								WOODBRIDGE							
		CRITICAL		DRY		NORMAL		WET		CRITICAL		DRY		NORMAL		WET	
OCT	1	103	*	103	*	161	*	161	*	20		20		20		20	
	2	103	*	200	*	341		341		20		117	$	200	$	200	$
NOV	1	157		257		357		357		100		200		300		300	
	2	157		257		357		357		100		200		300		300	
DEC	1	174		274		374		374		100		200		300		300	
	2	124		200		300		300		50	*	126	*	226	*	226	*
JAN	1	117		200		200		200		50	*	133	*	133	*	133	*
	2	117		200		200		200		50	*	133	*	133	*	133	*
FEB	1	110		200		200		200		50	*	140	*	140	*	140	*
	2	110		200		200		200		50	*	140	*	140	*	140	*
MAR	1	132		200		200		200		50	*	118	*	117	*	117	*
	2	132		200		200		200		50	*	118	*	117	*	117	*
APR	1	166		246		244		244		20	@	100		100		100	
	2	166		296		294		294		20	@	150		150		150	
MAY	1	232		512		599		599		20	@	300		300		300	
	2	232		612		699		699		20	@	400		400		400	
JUN	1	300		300		903		903		34	@	34	@	500		500	
	2	300		300		903		903		34	@	34	@	500	#	500	#
JUL	1	297	**	297	**	469		469		20	@	20	@	20	@	20	@
	2	297	**	297	**	469	**	469	**	20	@	20	@	20	@	20	@
AUG	1	257	**	257	**	398	**	398	**	20		20		20		20	
	2	257	**	257	**	398	**	398	**	20		20		20		20	
SEP	1	184	**	184	**	265	**	265	**	20		20		20		20	
	2	184	**	184	**	265	**	265	**	20		20		20		20	
AVERAGE FLOW (cfs)		184		260		375		375		40		116		175		175	
TOTAL FLOW (TAF)		133		188		271		271		29		84		127		127	

* Flow for steelhead, no flow requirement for chinook salmon
@ Trap and truck
$ This release should only be made if Camanche release temperature is 15.5 degrees C or less.
# This release should only be made when conditions in the Delta are conducive to smolt survival, otherwise release 20 cfs below Woodbridge and trap out-migrants.

4.4.4.3 Evaluation

The habitat analysis (Table 4.17) indicates that conditions would be generally good for each life stage of chinook salmon most of the time. The lowest value occurs during the out-migration period because of the high water temperature below Woodbridge Dam in dry and critical dry years. Out-migrating salmon would be trapped above Lake Lodi and trucked below the Delta at these times. Normal and wet year flows in the Camanche reach are better for spawning and out-migration than those in dry years but not as good for fry and juvenile rearing, which are optimized at lower flows (about 100 cfs, according to CDFG studies). Wet year impacts may reduce spawning effectiveness due to high, erosive flows.

Table 4.17. SCIES average scores by species and lifestage for natural production alternative.

SPECIES/REACH	LIFESTAGE	CRITICAL DRY	DRY	NORMAL	WET
Chinook Salmon					
Camanche Reach	In-migration	100	100	100	100
	Spawning	57	81	90	90
	Fry	99	75	75	75
	Juvenile	86	70	55	55
	Out-migration	99	99	100	100
Woodbridge Reach	In-migration	97	98	100	100
	Out-migration	20	45	83	83
Combined Reaches Scores		73	78	88	88
Steelhead Trout					
Camanche Reach	In-migration	100	100	100	100
	Spawning	60	94	93	93
	Fry	90	57	55	55
	Juvenile	79	70	59	59
	Out-migration	100	100	100	100
Woodbridge Reach	In-migration	100	100	100	100
	Out-migration	95	98	100	100
Combined Reaches Scores		92	92	91	91

Habitat conditions for steelhead would generally be good. The lowest scores occurred during the spawning period in critical dry years (due to lower than optimum flow) and during the rearing period in other years (due to slightly elevated water temperatures toward the end of the fry stage).

The life cycle for this alternative, depicted in Figure 4-5, uses a weighted average of the four types of year. Supporting assumptions and calculations are presented in Table 4.18 and Appendix E.

The frequency of year types is determined by using a combination of runoff projections and system storage. Frequencies were calculated from EBMUDSIM model results for the period 1921-1990. As in each of the other alternatives, an initial run of 5,000 salmon is divided into those returning to the hatchery (1,150) and those spawning naturally in the river (3,850). This alternative would require 7.18 million eggs to meet production goals; because Mokelumne returns would produce only 1.85 million eggs, 5 million of those would be imported as eggs or fry from other hatcheries.

Under this alternative, production from fish returning to the MRFH would be handled separately from imported eggs and fry. Production from Mokelumne River returns would be released as yearlings in the Mokelumne below Camanche Dam and as smolts when production is sufficiently high. This would increase natural returns to the Mokelumne. Production from imported eggs or fry would always be released below the Delta to augment harvest and returns to other parts of the Central Valley.

In critical dry years, river conditions would not be conducive to the survival of out-migrants below Woodbridge Dam, so all of the hatchery smolt production (including that derived from Mokelumne returns) would be trucked to a release point below the Delta or if conditions warranted they would be retained in the MRFH for planting in the river in the fall. The yearling program would function at its full capacity release of 800,000 below Camanche Dam in November and December, when conditions would be conducive to high survival.

In critical dry years, natural spawning in the river would yield about 1 million smolts (Table 4.18) but, because of conditions in Lake Lodi, all natural smolt production would be trapped above Lake Lodi at a proposed new trapping, tagging, and transportation facility. These fish would be trucked to a release point below the Delta unless conditions warranted holding some of them in the MRFH until the fall. The life cycle model indicates that a total of about 2.9 million smolts would reach Chipps Island in critically dry years (including those trucked from the hatchery and those trapped and trucked above Lake Lodi). About 360,000 yearlings would make it to Chipps Island. Standard survival and straying rates (Table 4.18) would yield a harvest of about 73,400, and the total number of returning spawners would reach about 37,800. However, only about 8,400 would return to the Mokelumne. Since all of the smolts would be trucked, their straying rates would be high (about 95%). Returns to the Mokelumne would result largely from the release of yearling fish. These fish would have a low straying rate (about 15%) because they would have migrated naturally out of the Mokelumne.

Two major changes would occur in dry years. River conditions would be maintained for out-migration through the end of May, so half of the hatchery smolt production derived from Mokelumne returns would be released below Camanche Dam in May and the other half would be trucked to a release point below the Delta in June and July. Survival in Lake Lodi

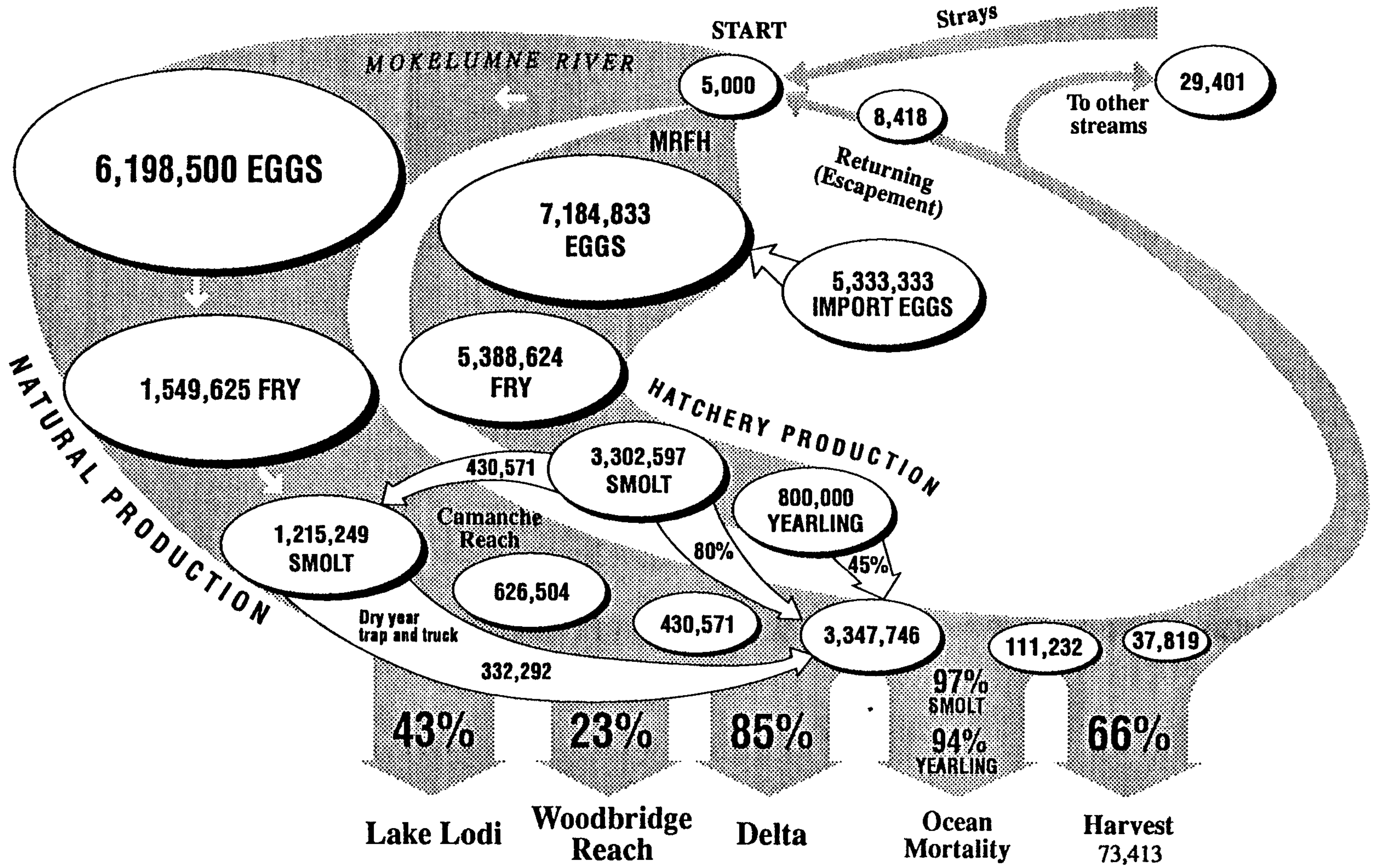

Figure 4-5. Production-oriented alternative (natural emphasis) life cycle model. 9/92

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Table 4.18. Production-oriented (natural emphasis) alternative life cycle model output (see Appendix E for more detail).

Rates in the top part of Table are used to calculate numbers in lower part of table. Equations for each calculation are given to the right of the appropriate row.

ROW	SURVIVAL RATES	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR
1	YEAR TYPE FREQUENCY OF OCCURENCE	16%	34%	36%	14%
2	FEMALES IN RUN	35%	35%	35%	35%
3	NUMBER OF EGGS PER FEMALE	4600	4600	4600	4600
4	EGG TO FRY SURVIVAL	25%	25%	25%	25%
5	FRY TO SMOLT SURVIVAL	68%	68%	68%	68%
6	OUTMIGRANT SURVIVAL TO L. LODI	95%	95%	95%	95%
7	SURVIVAL THROUGH L. LODI	32%	49%	70%	70%
8	OUTMIGRANTS TRAPPED AND TRUCKED	100%	50%	0%	0%
9	OUTMIGRANT SURVIVAL FROM WOODBRIDGE TO DELTA	20%	45%	83%	83%
10	OUTMIGRANT SURVIVAL THROUGH DELTA	15%	15%	15%	15%
11	SURVIVAL OF SMOLTS RELEASED IN DELTA	80%	80%	80%	80%
12	SURVIVAL OF YEARLINGS RELEASED IN DELTA	90%	90%	90%	90%
13	SURVIVAL OF YEARLINGS RELEASED AT MRFH	45%	45%	45%	45%
14	OCEAN SURVIVAL OF SMOLTS	3%	3%	3%	3%
15	OCEAN SURVIVAL OF YEARLINGS	6%	6%	6%	6%
16	SURVIVING HARVEST	34%	34%	34%	34%
17	NATURAL OUTMIGRANT STRAYING RATE	15%	15%	15%	15%
18	DELTA RELEASE STRAYING RATE	95%	95%	95%	95%

ROW	NUMBERS OF FISH	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR	WEIGHTED AVERAGE	
19	INITIAL TOTAL NUMBER OF SPAWNERS	5000	5000	5000	5000	5000	
	HATCHERY						
20	NUMBER OF SPAWNERS ENTERING HATCHERY	1150	1150	1150	1150	1150	
21	EGGS FROM FISH RETURNING TO HATCHERY	1851500	1851500	1851500	1851500	1851500	
22	TOTAL HATCHERY EGGS NEEDED	7262338	7262338	7262338	7262338	7262338	
23	EGGS OR FRY IMPORTED FROM OTHER HATCHERY	5410838	5410838	5410838	5410838	5410838	
24	NUMBER OF SMOLTS RELEASED AT MRFH	0	155450	310900	310900	208303	
25	NUMBER OF SMOLTS RELEASED IN DELTA	3557403	3401953	3246503	3246503	3349100	
26	NUMBER OF YEARLINGS RELEASED AT MRFH	800000	800000	800000	800000	800000	
27	NUMBER OF YEARLINGS RELEASED IN DELTA	0	0	0	0	0	
	RIVER						
28	NUMBER SPAWNING NATURALLY IN RIVER	3850	3850	3850	3850	3850	
29	EGGS DEPOSITED IN RIVER	6198500	6198500	6198500	6198500	6198500	
30	FRY HATCHING IN RIVER	1549625	1549625	1549625	1549625	1549625	
31	NATURAL SMOLTS ENTERING LAKE LODI	1006946	1006946	1006946	1006946	1006946	
32	TOTAL SMOLTS ENTERING LAKE LODI	0	658923	1317846	1317846	882957	
33	SMOLTS SURVIVING LAKE LODI	0	322872	922492	922492	571023	
34	NUMBER OF SMOLTS TRAPPED AND TRUCKED	1006946	503473	0	0	332292	
35	SMOLTS MIGRATING NATURALLY TO DELTA	0	145293	765669	765669	432234	
36	NATURALLY PRODUCED SMOLTS TO DELTA	0	129011	594067	594067	340898	
37	SMOLTS MIGRATING NATURALLY TO CHIPPS ISLAND	0	21794	114850	114850	64835	
38	SMOLTS TRUCKED TO CHIPPS ISLAND	3651479	3124341	2597202	2597202	2945114	
39	TOTAL SMOLTS TO CHIPPS ISLAND	3651479	3146135	2712053	2712053	3009949	
40	YEARLINGS TO CHIPPS ISLAND	360000	360000	360000	360000	360000	
41	NUMBER SURVIVING TO BE HARVESTED OR SPAWN	131144	115984	102962	102962	111898	
42	NUMBER HARVESTED	86555	76549	67955	67955	73853	
43	TOTAL NUMBER LEFT TO SPAWN	44589	39435	35007	35007	38045	
44	NUMBER STRAYING TO OTHER RIVERS	36484	31410	26444	26444	29739	
45	NUMBER RETURNING TO MOKELUMNE	8105	8025	8563	8563	8307	
	NATURAL SMOLTS RETURNING	0	189	996	996	562	7%
	TRUCKED SMOLTS RETURNING	1862	1593	1325	1325	1502	18%
	RIVER YEARLINGS RETURNING	6242	6242	6242	6242	6242	75%
	DELTA YEARLINGS RETURNING	0	0	0	0	0	0%
		8105	8025	8563	8563	8307	

also would be higher because of greater bypass flows (Section 3.0); thus, natural out-migrants would not be trapped and trucked until after 1 June. This would allow about half of the fish produced to migrate naturally through the lower river.

In dry years, a total of about 3.1 million smolts would be produced (as estimated at Chipps Island). In critical dry years, the number would be slightly less because, although more fish migrate naturally, they would have a lower survival rate than those that were trucked. The end result is that more fish would return to the Mokelumne, but slightly fewer would be harvested or would return to other rivers.

In normal and wet years, river conditions would remain good through the end of June. All Mokelumne-origin hatchery production would be released below Camanche Dam. The rate of out-migrant survival through Lake Lodi would be relatively high (70%), and no fish would be trapped or trucked. As in dry years, these practices would lead to slightly lower overall smolt production, harvest, and system escapement than other alternatives, but greater returns to the Mokelumne.

Over all year types, this alternative would achieve the highest level of total smolt production (about 3 million predicted at Chipps Island). Out-migration flows would minimize losses in Lake Lodi and maintain suitable temperatures between Lake Lodi and the Delta, so natural smolt production would also be fairly high (430,000). This is lower than natural smolt production under the CDFG Plan since smolts are trapped and trucked in some years. Harvest and total escapement would be about average for this alternative (Table 4.18).

By optimizing in-river production in wet, normal, and (to a lesser degree) dry years, this alternative would reduce in-river flow during critically dry years when storage and projected runoff are both at minimum levels. Adverse impacts to the fishery in critically dry years would be offset by trucking production to release points below the Delta or making releases in the fall when conditions improve.

The life cycle model predicts an average return of more than 8,400 salmon from an initial average run of 5,000. This indicates an increasing population. In all, 88 percent of Mokelumne returns would be comprised of fish originating in the Mokelumne, either as naturally out-migrating smolts (12%) or yearlings (76%) (Table 4.19). The balance (12%) would originate from the Delta smolt releases produced mostly from imported eggs or fry. The returns would rely heavily on releases of yearlings in the Mokelumne; this should be considered experimental. The MRFH would need to be substantially modified to handle the increased production, particularly of yearlings, and separate holding facilities would be required for Mokelumne and imported stocks (Section 5.2).

Table 4.19. Production-oriented (hatchery emphasis) alternative life cycle model output (see Appendix E for more detail).

Rates in the top part of Table are used to calculate numbers in lower part of table. Equations for each calculation are given to the right of the appropriate row.

ROW	SURVIVAL RATES	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR
1	YEAR TYPE FREQUENCY OF OCCURENCE	46%	18%	18%	18%
2	FEMALES IN RUN	35%	35%	35%	35%
3	NUMBER OF EGGS PER FEMALE	4600	4600	4600	4600
4	EGG TO FRY SURVIVAL	25%	25%	25%	25%
5	FRY TO SMOLT SURVIVAL	68%	68%	68%	68%
6	OUTMIGRANT SURVIVAL TO L. LODI	95%	95%	95%	95%
7	SURVIVAL THROUGH L. LODI	40%	51%	54%	54%
8	OUTMIGRANTS TRAPPED AND TRUCKED	100%	0%	0%	0%
9	OUTMIGRANT SURVIVAL FROM WOODBRIDGE TO DELTA	24%	44%	44%	44%
10	OUTMIGRANT SURVIVAL THROUGH DELTA	15%	15%	15%	15%
11	SURVIVAL OF SMOLTS RELEASED IN DELTA	80%	80%	80%	80%
12	SURVIVAL OF YEARLINGS RELEASED IN DELTA	90%	90%	90%	90%
13	SURVIVAL OF YEARLINGS RELEASED AT MRFH	45%	45%	45%	45%
14	OCEAN SURVIVAL OF SMOLTS	3%	3%	3%	3%
15	OCEAN SURVIVAL OF YEARLINGS	6%	6%	6%	6%
16	SURVIVING HARVEST	34%	34%	34%	34%
17	NATURAL OUTMIGRANT STRAYING RATE	15%	15%	15%	15%
18	DELTA RELEASE STRAYING RATE	95%	95%	95%	95%

ROW	NUMBERS OF FISH	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR	WEIGHTED AVERAGE	
19	INITIAL TOTAL NUMBER OF SPAWNERS	5000	5000	5000	5000	5000	
	HATCHERY						
20	NUMBER OF SPAWNERS ENTERING HATCHERY	1150	1150	1150	1150	1150	
21	EGGS FROM FISH RETURNING TO HATCHERY	1851500	1851500	1851500	1851500	1851500	
22	TOTAL HATCHERY EGGS NEEDED	6851500	6851500	6851500	6851500	6851500	
23	EGGS OR FRY IMPORTED FROM OTHER HATCHERY	5000000	5000000	5000000	5000000	5000000	
24	NUMBER OF SMOLTS RELEASED AT MRFH	0	310900	310900	310900	167886	
25	NUMBER OF SMOLTS RELEASED IN DELTA	3310900	3000000	3000000	3000000	3143014	
26	NUMBER OF YEARLINGS RELEASED AT MRFH	800000	800000	800000	800000	800000	
27	NUMBER OF YEARLINGS RELEASED IN DELTA	0	0	0	0	0	
	RIVER						
28	NUMBER SPAWNING NATURALLY IN RIVER	3850	3850	3850	3850	3850	
29	EGGS DEPOSITED IN RIVER	6198500	6198500	6198500	6198500	6198500	
30	FRY HATCHING IN RIVER	1549625	1549625	1549625	1549625	1549625	
31	NATURAL SMOLTS ENTERING LAKE LODI	1006946	1006946	1006946	1006946	1006946	
32	TOTAL SMOLTS ENTERING LAKE LODI	1006946	1302301	1302301	1302301	1166438	
33	SMOLTS SURVIVING LAKE LODI	402779	664174	703243	703243	557997	
34	NUMBER OF SMOLTS TRAPPED AND TRUCKED	402779	0	0	0	185278	
35	SMOLTS MIGRATING NATURALLY TO DELTA	0	292236	309427	309427	163996	
36	NATURALLY PRODUCED SMOLTS TO DELTA	0	225959	239250	239250	126803	
37	SMOLTS MIGRATING NATURALLY TO CHIPPS ISLAND	0	43835	46414	46414	24599	
38	SMOLTS TRUCKED TO CHIPPS ISLAND	2970943	2400000	2400000	2400000	2662634	
39	TOTAL SMOLTS TO CHIPPS ISLAND	2970943	2443835	2446414	2446414	2687233	
40	YEARLINGS TO CHIPPS ISLAND	360000	360000	360000	360000	360000	
41	NUMBER SURVIVING TO BE HARVESTED OR SPAWN	110728	94915	94992	94992	102217	
42	NUMBER HARVESTED	73081	62644	62695	62695	67463	
43	TOTAL NUMBER LEFT TO SPAWN	37648	32271	32297	32297	34754	
44	NUMBER STRAYING TO OTHER RIVERS	29890	24425	24429	24429	26940	
45	NUMBER RETURNING TO MOKELUMNE	7758	7846	7869	7869	7814	
	NATURAL SMOLTS RETURNING	0	380	402	402	213	3%
	TRUCKED SMOLTS RETURNING	1515	1224	1224	1224	1358	17%
	RIVER YEARLINGS RETURNING	6242	6242	6242	6242	6242	80%
	DELTA YEARLINGS RETURNING	0	0	0	0	0	0%
		7758	7846	7869	7869	7814	

4.4.5 Production-Oriented Alternative, Hatchery Emphasis

4.4.5.1 Rationale

This approach is similar to the production/natural emphasis approach except that it does not stress river production. This approach minimizes flow releases for fishery purposes while using the MRFH to maintain a high level of production, ocean harvest, and returns to the Central Valley and Mokelumne River.

One objective of this alternative is to improve imprinting of smolts and yearlings to the Mokelumne so that these fish will return to the Mokelumne as adults; high flows would not be needed to attract stray salmon into the river as in the escapement-oriented alternative.

4.4.5.2 Implementation

Flow recommendations for this alternative are presented in Table 4.20. The flows would be implemented as shown in Table 4.21. Minimum flows (50 cfs until November 15, 100 cfs thereafter) would be provided below Woodbridge during the fall migration to allow salmon adequate passage to the spawning area.

This alternative would provide 50 percent of optimum spawning habitat in critical dry years and 70 percent in all other types of years (based on CDFG IFIM study). It would also provide optimum flow for rearing. Modeling studies indicate that critically dry flows would occur in 16 percent of all years during the spawning period.

Naturally-produced smolts would be trapped above Lake Lodi and trucked to release points below the Delta at all times, except when conditions (i.e., good water temperatures) allow out-migration in the river. Modeling studies indicate that trapping and trucking would be needed 46 percent of the time (Appendix D).

The MRFH would be operated to maximize returns of Mokelumne River fish by taking eggs from salmon returning to the Mokelumne River and returning them to the Mokelumne as smolts and yearlings. Of these, 800,000 would be reared to yearlings and planted in the Mokelumne River. The remaining eggs would be reared to smolts and released in the Mokelumne when conditions are most favorable for their survival (before water temperatures and diversions increase or after the problems cease in the fall). Eggs imported from other hatcheries would be reared separately and planted as smolts in the Delta to enhance ocean harvest and returns to other parts of the Central Valley.

4.4.5.3 Evaluation

Total smolt production (including those trucked below the Delta) would be about the same as the production/natural alternative and higher than other alternatives (Table 4.22). Harvest and total escapement would be about average. The number of yearlings produced and the

Table 4.20. Recommended flows for production-oriented alternative (hatchery emphasis).

		CAMANCHE CRITICAL		CAMANCHE ALL OTHER		WOODBRIDGE CRITICAL		WOODBRIDGE ALL OTHER	
OCT	1	100	*	100	*	50		50	
	2	100	*	100	*	50		50	
NOV	1	100		100		50		50	
	2	100		150		50		100	
DEC	1	100		150		50		100	
	2	100		150		50	*	100	*
JAN	1	100		150		50	*	100	*
	2	100		150		50	*	100	*
FEB	1	100		150		50	*	100	*
	2	100		150		50	*	100	*
MAR	1	100		100		50	*	50	*
	2	100		100		50	*	50	*
APR	1	100		100		50	@	50	
	2	100		100		50	@	50	
MAY	1	100		150	$	50	@	100	#
	2	100		200	$	50	@	150	#
JUN	1	100		250	$	50	@	200	#
	2	100		300	$	50	@	250	#
JUL	1	100	*	100	*	50	@	50	@
	2	100	*	100	*	50	@	50	@
AUG	1	100	*	100	*	50		50	
	2	100	*	100	*	50		50	
SEP	1	100	*	100	*	50		50	
	2	100	*	100	*	50		50	
AVERAGE FLOW (cfs)		100		135		50		85	
TOTAL FLOW (TAF)		72		98		36		62	

* Flow for steelhead, no flow requirement for chinook salmon
@ Trap and truck
$ Flows provided if sufficient storage and runoff, otherwise 100 cfs.
# Flows provided if sufficient storage and runoff, otherwise 50 cfs.

Table 4.21. Implementation flows for production-oriented alternative (hatchery emphasis).

		CAMANCHE				WOODBRIDGE			
		CRITICAL	DRY	NORMAL	WET	CRITICAL	DRY	NORMAL	WET
OCT	1	133	133	133 *	133 *	50	50	50	50
	2	133	133	133 *	133 *	50	50	50	50
NOV	1	107	107	107	107	50	50	50	50
	2	107	157	157	157	50	100	100	100
DEC	1	124	174	174	174	50	100	100	100
	2	124	174	174	174	50	100	100 *	100 *
JAN	1	117	167	167	167	50	100	100 *	100 *
	2	117	167	167	167	50	100	100 *	100 *
FEB	1	110	160	160	160	50	100	100 *	100 *
	2	110	160	160	160	50	100	100 *	100 *
MAR	1	132	132	132	132	50	50	50 *	50 *
	2	132	132	132	132	50	50	50 *	50 *
APR	1	196	196	196	196	50	50	50 @	50
	2	196	196	196	196	50	50	50 @	50
MAY	1	262	312	312	312 $	50	100	100 @	100 #
	2	262	362	362	362 $	50	150	150 @	150 #
JUN	1	316	466	466	466 $	50	200	200 @	200 #
	2	316	516	516	516 $	50	250	250 @	250 #
JUL	1	327	327	327 *	327 *	50	50	50 @	50 @
	2	327	327	327 *	327 *	50	50	50 @	50 @
AUG	1	287	287	287 *	287 *	50	50	50	50
	2	287	287	287 *	287 *	50	50	50	50
SEP	1	214	214	214 *	214 *	50	50	50	50
	2	214	214	214 *	214 *	50	50	50	50
AVERAGE FLOW (cfs)		194	229	229	229	50	85	85	85
TOTAL FLOW (TAF)		140	166	166	166	36	62	62	62

* Flow for steelhead, no flow requirement for chinook salmon
@ Trap and truck
$ Flows provided if sufficient storage and runoff, otherwise 100 cfs.
# Flows provided if sufficient storage and runoff, otherwise 50 cfs.

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Table 4.22. Fishery benefits of management alternatives.

MANAGEMENT ALTERNATIVE	CHINOOK SALMON PREDICTED FISHERY BENEFITS						
	INITIAL RUN SIZE	TOTAL SMOLT PRODUCTION (1)	TOTAL YEARLING PRODUCTION (1)	NATURAL SMOLTS (2)	HARVEST	SYSTEM ESCAPEMENT (3)	MOKELUMNE RETURNS
CDFG PLAN	5,000	1,685,192	675,000	567,948	60,097	30,959	13,259
ESCAPEMENT ALTERNATIVE	5,000	131,406	339,366	1,006,946	50,905	1,201,125	66,181
PRODUCTION, NATURAL EMPHASIS	5,000	3,009,949	360,000	340,898	73,853	38,045	8,307
PRODUCTION, HATCHERY EMPHASIS	5,000	126,803	24,599	557,997	2,687,233	360,000	34,754
MAXIMUM HARVEST	5,000	0	233,450	291,813	3,149,820	195,993	63,306
BASE CASE, 1961 CDFG AGREEMENT	5,000	0	1,337,193	301,492	477,000	68,736	22,202
EXISTING FLOW CONDITION	5,000	87,687	1,134,698	48,373	477,000	65,292	20,374

(1) Total smolt and yearling production measured at Chipps Island
(2) Natural smolt production measured at mouth of the Mokelumne (near Thornton)
(3) System escapement includes returns to all Central Valley streams and hatcheries (Sacramento and San Joaquin watersheds).

necessity of holding them over the summer would require improvements at the MRFH. The major difference between this alternative and the production-oriented/natural emphasis alternative is that the natural emphasis alternative would yield more than two and a half times the number of natural smolts migrating out of the Mokelumne River.

The habitat analysis (Table 4.23) indicates that conditions would be generally good for each life stage of chinook salmon most of the time. Low values would occur, however, during the out-migration period because of high water temperatures below Woodbridge. Fry and juvenile rearing, optimized at lower flows (100 cfs), would score well under this alternative. The minimum habitat value would occur below Woodbridge during out-migration. Flows are rarely high enough to mitigate the effects of high temperatures, so fish are usually trapped and trucked.

Table 4.23. SCIES average scores by species and lifestage for hatchery production alternative.

SPECIES/REACH	LIFESTAGE	CRITICAL DRY	DRY	NORMAL	WET
Chinook Salmon					
Camanche Reach	In-migration	100	100	100	100
	Spawning	50	60	60	60
	Fry	97	91	91	91
	Juvenile	83	75	75	75
	Out-migration	99	99	99	99
Woodbridge Reach	In-migration	97	97	97	97
	Out-migration	24	44	44	44
Combined Reaches Scores		73	78	78	78
Steelhead Trout					
Camanche Reach	In-migration	100	100	100	100
	Spawning	59	72	72	72
	Fry	86	79	79	79
	Juvenile	78	74	74	74
	Out-migration	100	100	100	100
Woodbridge Reach	In-migration	100	100	100	100
	Out-migration	96	97	97	97
Combined Reaches Scores		91	92	92	92

Habitat conditions for steelhead also would be generally good. The lowest values would occur during the spawning period in all years, which would still provide 59 to 72 percent of optimal habitat.

The life cycle for this alternative, depicted in Figure 4-6, uses a weighted average of the four types of year. Supporting assumptions and calculations are presented in Table 4.19 and Appendix E.

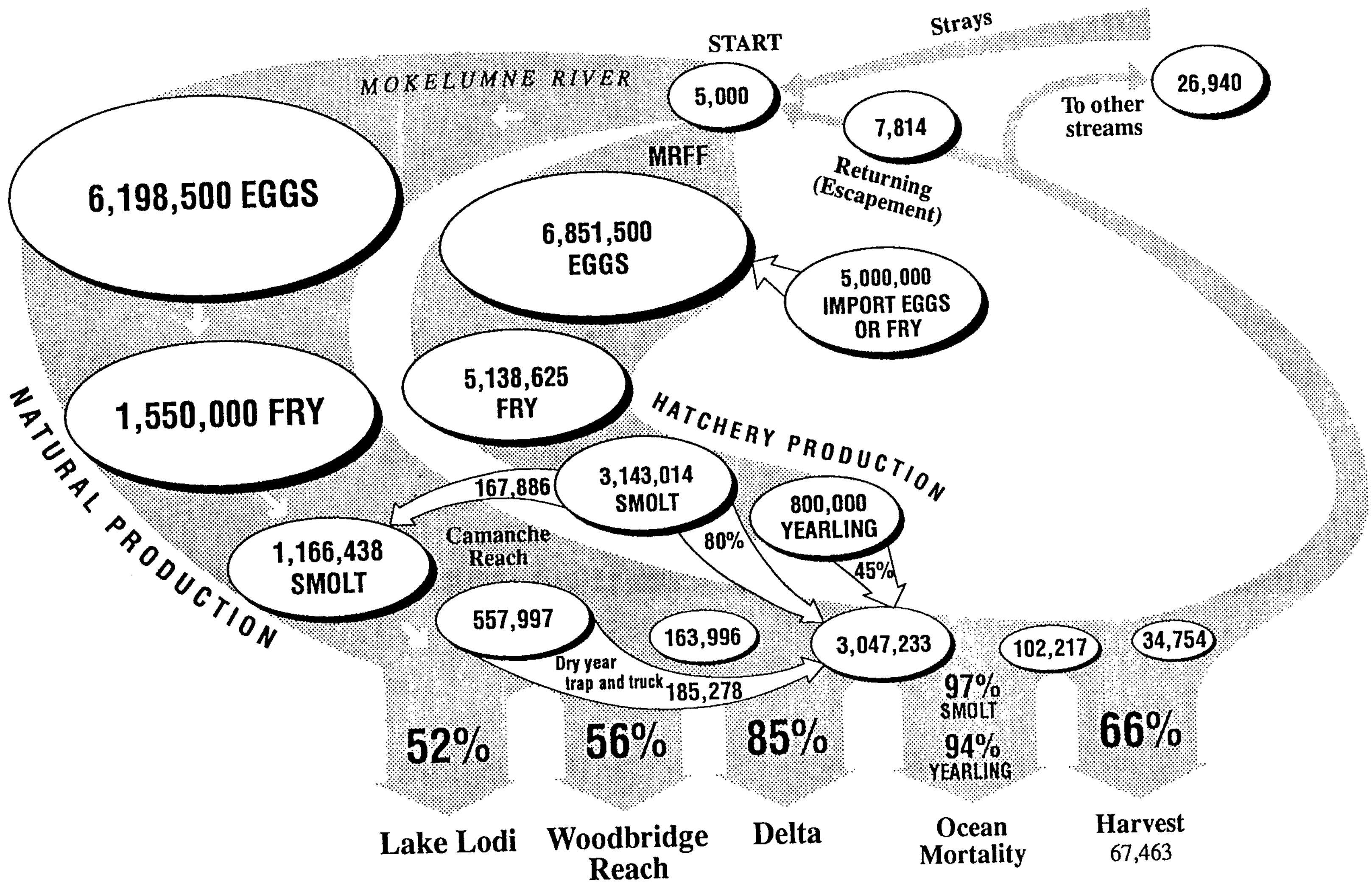

Figure 4-6. Production-oriented alternative (hatchery emphasis) life cycle model.

The frequency of year types is determined by using a combination of runoff projections and system storage. Frequencies were determined from EBMUDSIM model results for the period 1921-1990. As in each of the other alternatives, an initial run of 5,000 salmon is split into those returning to the hatchery (1,150) and those spawning naturally in the river (3,850). Under this alternative, the hatchery would be operated in a manner similar to that outlined in the production-oriented/natural approach.

This alternative would provide a minimal level of spawning habitat (about 50% of optimum in critically dry years and about 70% in other years). Although hatching and emergence would probably be lower under this alternative than assumed in the life cycle model, the data are insufficient to quantify the difference.

The major difference between this alternative and the production-oriented/natural alternative is demonstrated in the survival rate through Lake Lodi and the migration from Woodbridge Dam to the Delta (Tables 4.19 and 4.18). Relatively low bypass flows would be provided in all years at the WID diversion, resulting in a relatively low survival rate through Lake Lodi. Relatively low flows below Woodbridge would result in high water temperatures and a correspondingly low survival rate (25% in critically dry years, 44% in other years), because this alternative would rely on the hatchery for the bulk of its production. Naturally-produced smolts would be trapped and trucked in critical dry years and after 30 June in all other years.

Total smolt production, estimated at Chipps Island, would be similar to the production-oriented/natural alternative (2.7 million). Yearling production would be identical; however, natural smolt production would differ from the production/natural alternative. The production-oriented/hatchery alternative would produce about 127,000 smolts at the mouth of the Mokelumne, while the production-oriented/natural alternative would produce about 330,000, or more than 2.5 times as many. Although harvest and system escapement would be similar for the two alternatives, the decrease in natural smolt production would result in fewer returns to the Mokelumne River under the production/hatchery alternative.

The life cycle model predicts an average return of almost 7,800 salmon from an initial average run of 5,000, indicating an increasing population. In all, 81 percent of Mokelumne returns would be comprised of fish that originated in the Mokelumne, either as naturally out-migrating smolts (1%) or yearlings (80%). The balance (19%) would come from the Delta smolt releases, produced mostly from imported eggs or fry. The returns would rely heavily on releases of yearlings in the Mokelumne, which should be considered experimental.

4.4.6 Harvest-Oriented Alternative

4.4.6.1 Rationale

Because harvest is the major benefit of salmon management, this alternative would measure its success in terms of the ocean harvest of salmon. The central strategy of this approach would be to rear large numbers of salmon to yearling stage and release them below the

Delta. Although the river above Lake Lodi would be managed to enhance natural production, this represents a small component of the total harvest.

4.4.6.2 Implementation

Flow recommendations shown in Table 4.24 would be implemented as shown in Table 4.25. This alternative would provide fall flows for upstream migration of returning Mokelumne River salmon. Modeling indicates that, under this scenario, a significant number of salmon would return to the Mokelumne without the need for high attraction flows. Although the migration flows needed for steelhead are uncertain, a flow below Woodbridge of 50 cfs in critical years and 100 cfs in other years between December and March should allow for steelhead migration.

Above Lake Lodi, this alternative would provide river habitat for salmon and steelhead spawning and rearing similar to that in the production-oriented/natural alternative. Water temperature constraints and weighted usable habitat area (based on CDFG 1991 studies) would be balanced to provide optimum conditions in normal and wet years. These constraints would be relaxed somewhat to less than optimum conditions in dry years and to minimum levels for maintenance in critical dry years.

Because this alternative aims to maximize returns to the ocean fishery, all naturally-produced smolts would be trapped above Lake Lodi and trucked to a release point below the Delta. There would be no flow requirement for emigration below Woodbridge.

The MRFH would be operated to maximize harvest. Available data indicate that the highest rate of return to the ocean fishery would be obtained by rearing salmon to yearling size and releasing them below the Delta. Larger fish released in the fall below Chipps Island would have the highest survival rates and, therefore, contribute more to the ocean fishery than smaller fish or those released further upstream. Yearlings would have to be held during the summer at the hatchery with good temperature and water quality conditions, and the hatchery would need to be substantially upgraded to manage the number of yearlings proposed.

4.4.6.3 Evaluation

This alternative would provide almost twice as much harvest as any other alternative (Table 4.22). Smolt production would be low and composed only of naturally-produced fish trucked below the Delta. Although straying rates would be high, the large number planted should result in significant returns to the Mokelumne River. Although comparisons of the released smolt-size and yearling-size fish indicate that yearlings contribute more to the fishery, the studies were not comprehensive and the findings are not consistent (Section 3.0). A program based only on yearling releases would be highly experimental. The number of yearlings involved and the need to hold them over summer would require substantial improvements at the MRFH.

Table 4.24. Recommended flows for maximum harvest alternative (hatchery emphasis).

		CAMANCHE REACH						WOODBRIDGE REACH					
		CRITICAL		DRY		NORMAL AND WET		CRITICAL		DRY		NORMAL AND WET	
OCT	1	100	*	100	*	100	*	20		20		20	
	2	100	*	200	$	300	$	20	$	100	$	200	$
NOV	1	100		200		300		100		200		300	
	2	100		200		300		100		200		300	
DEC	1	100		200		300		100		200		300	
	2	100		200		300		50	*	50	*	50	*
JAN	1	100		200		200		50	*	50	*	50	*
	2	100		200		200		50	*	50	*	50	*
FEB	1	100		200		200		50	*	50	*	50	*
	2	100		200		200		50	*	50	*	50	*
MAR	1	100		200		200		50	*	50	*	50	*
	2	100		200		200		50	*	50	*	50	*
APR	1	100		100		100		20	@	20	@	20	@
	2	100		100		100		20	@	20	@	20	@
MAY	1	100		100		100		20	@	20	@	20	@
	2	100		100		100		20	@	20	@	20	@
JUN	1	300		300		300		20	@	20	@	20	@
	2	300		300		300		20	@	20	@	20	@
JUL	1	100	*	200	*	450		20	@	20	@	20	@
	2	100	*	200	*	200	*	20	@	20	@	20	@
AUG	1	100	*	200	*	200	*	20		20		20	
	2	100	*	200	*	200	*	20		20		20	
SEP	1	100	*	100	*	100	*	20		20		20	
	2	100	*	100	*	100	*	20		20		20	
AVERAGE FLOW (cfs)		117		179		210		39		55		71	
TOTAL FLOW (TAF)		84		130		152		28		40		52	

* Flow for steelhead, no flow requirement for chinook salmon
@ Trap and truck
$ This release should only be made if Camanche release temperature is 15.5 degrees C or less.

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Table 4.25. Implementation flows for maximum harvest alternative (hatchery emphasis).

		CAMANCHE REACH CRITICAL		CAMANCHE REACH DRY		CAMANCHE REACH NORMAL AND WET		WOODBRIDGE REACH CRITICAL		WOODBRIDGE REACH DRY		WOODBRIDGE REACH NORMAL AND WET	
OCT	1	103	*	103	*	161	*	20		20		20	
	2	103	*	200	$	341	$	20	$	117	$	200	$
NOV	1	157		257		357		100		200		300	
	2	157		257		357		100		200		300	
DEC	1	174		274		374		100		200		300	
	2	124		200		300		50	*	126	*	226	*
JAN	1	117		200		200		50	*	133	*	133	*
	2	117		200		200		50	*	133	*	133	*
FEB	1	110		200		200		50	*	140	*	140	*
	2	110		200		200		50	*	140	*	140	*
MAR	1	132		200		200		50	*	118	*	117	*
	2	132		200		200		50	*	118	*	117	*
APR	1	166		166		164		20	@	20	@	20	@
	2	166		166		164		20	@	20	@	20	@
MAY	1	232		232		319		20	@	20	@	20	@
	2	232		232		319		20	@	20	@	20	@
JUN	1	300		300		423		34	@	34	@	20	@
	2	300		300		423		34	@	34	@	20	@
JUL	1	297	*	297	*	469		20	@	20	@	20	@
	2	297	*	297	*	469	*	20	@	20	@	20	@
AUG	1	257	*	257	*	398	*	20		20		20	
	2	257	*	257	*	398	*	20		20		20	
SEP	1	184	*	184	*	265	*	20		20		20	
	2	184	*	184	*	265	*	20		20		20	
AVERAGE FLOW (cfs)		184		223		299		40		80		99	
TOTAL FLOW (TAF)		133		162		216		29		58		71	

* Flow for steelhead, no flow requirement for chinook salmon
@ Trap and truck
$ This release should only be made if Camanche release temperature is 15.5 degrees C or less.

The habitat analysis (Table 4.26) indicates that habitat conditions for chinook salmon and steelhead spawning and rearing would be well maintained in Camanche reach. Because all naturally-produced smolts would be trapped and trucked, no provisions would be made for natural out-migration below Woodbridge. This is reflected in the low scores for the Woodbridge reach during out-migration. The minimum habitat value would occur during the out-migration period below Woodbridge. Smolts are trapped and trucked at these times.

Table 4.26. SCIES average scores by species and lifestage for maximum harvest alternative.

SPECIES/REACH	LIFESTAGE	CRITICAL DRY	DRY	NORMAL	WET
Chinook Salmon					
Camanche Reach	In-migration	100	100	100	100
	Spawning	57	81	90	90
	Fry	99	78	78	78
	Juvenile	86	84	78	78
	Out-migration	99	99	100	100
Woodbridge Reach	In-migration	97	98	100	100
	Out-migration	20	20	37	37
Combined Reaches Scores		73	74	79	79
Steelhead Trout					
Camanche Reach	In-migration	100	100	100	100
	Spawning	60	92	91	91
	Fry	90	67	66	66
	Juvenile	79	75	68	68
	Out-migration	100	100	100	100
Woodbridge Reach	In-migration	100	100	100	100
	Out-migration	95	95	96	96
Combined Reaches Scores		92	92	92	92

Although steelhead are not a focus of management objective under this alternative, habitat conditions for steelhead would be generally good.

The life cycle for this alternative, depicted in Figure 4-7, uses a weighted average of the four year types. Supporting assumptions and calculations are presented in Table 4.27 and Appendix E.

The frequency of year types has not yet been determined because this alternative has not been run through EBMUDSIM. It was assumed for this analysis that year type frequency would be similar to the production-oriented/natural alternative. In any case, there would be very little difference in production between year types for this alternative. As in each of the other alternatives, an initial run of 5,000 salmon would be split into those returning to the hatchery (1,150) and those spawning naturally in the river (3,850). This alternative would

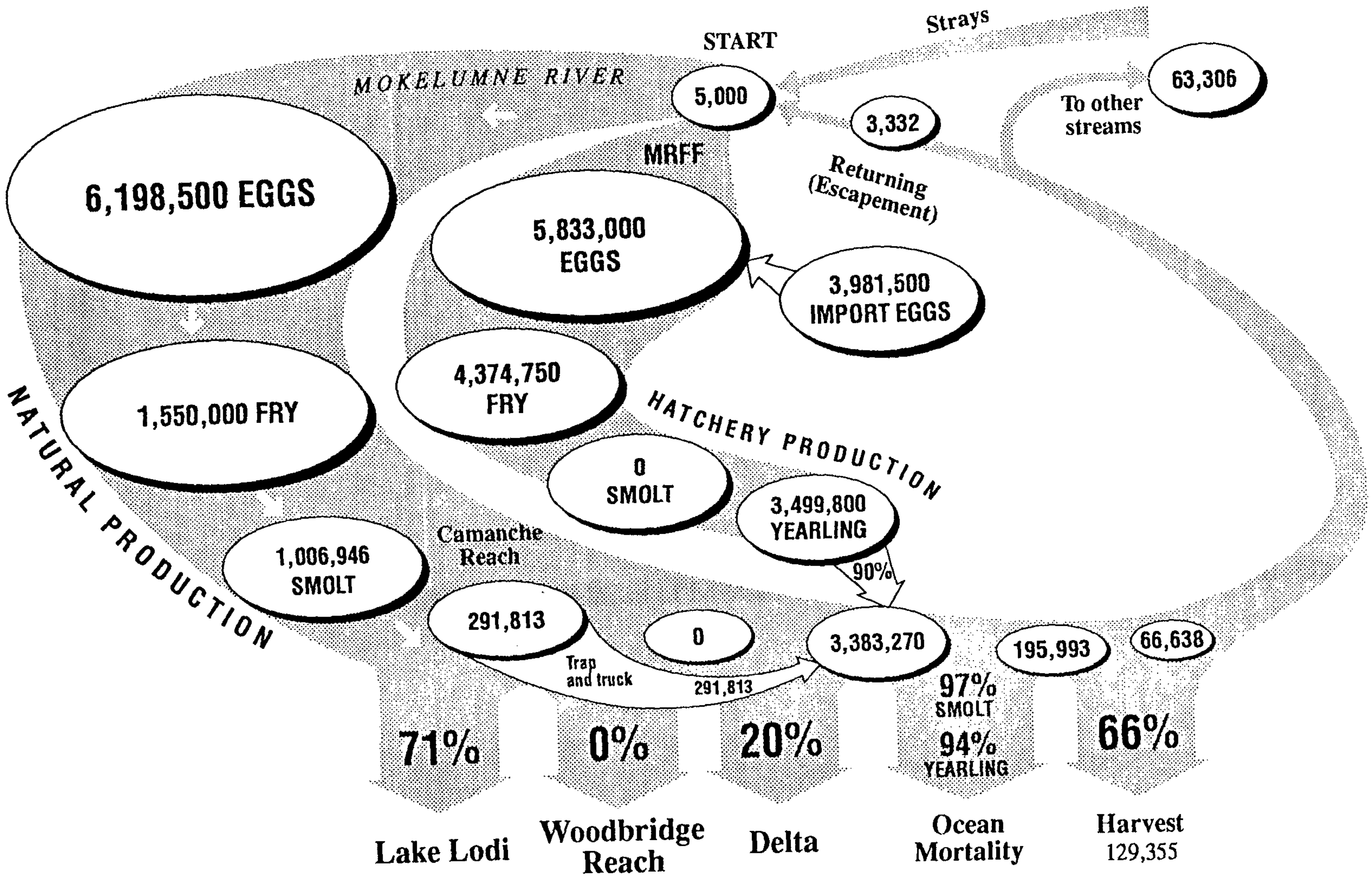

Figure 4-7. Harvest-oriented alternative life cycle model.

Table 4.27. Maximum harvest alternative life cycle model output (see Appendix E for more detail).

Rates in the top part of Table are used to calculate numbers in lower part of table. Equations for each calculation are given to the right of the appropriate row.

ROW	SURVIVAL RATES	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR
1	YEAR TYPE FREQUENCY OF OCCURENCE	16%	34%	36%	14%
2	FEMALES IN RUN	35%	35%	35%	35%
3	NUMBER OF EGGS PER FEMALE	4600	4600	4600	4600
4	EGG TO FRY SURVIVAL	25%	25%	25%	25%
5	FRY TO SMOLT SURVIVAL	68%	68%	68%	68%
6	OUTMIGRANT SURVIVAL TO L. LODI	95%	95%	95%	95%
7	SURVIVAL THROUGH L. LODI	32%	29%	28%	28%
8	OUTMIGRANTS TRAPPED AND TRUCKED	100%	100%	100%	100%
9	OUTMIGRANT SURVIVAL FROM WOODBRIDGE TO DELTA	20%	20%	37%	37%
10	OUTMIGRANT SURVIVAL THROUGH DELTA	15%	15%	15%	15%
11	SURVIVAL OF SMOLTS RELEASED IN DELTA	80%	80%	80%	80%
12	SURVIVAL OF YEARLINGS RELEASED IN DELTA	90%	90%	90%	90%
13	SURVIVAL OF YEARLINGS RELEASED AT MRFH	45%	45%	45%	45%
14	OCEAN SURVIVAL OF SMOLTS	3%	3%	3%	3%
15	OCEAN SURVIVAL OF YEARLINGS	6%	6%	6%	6%
16	SURVIVING HARVEST	34%	34%	34%	34%
17	NATURAL OUTMIGRANT STRAYING RATE	15%	15%	15%	15%
18	DELTA RELEASE STRAYING RATE	95%	95%	95%	95%

ROW	NUMBERS OF FISH	CRITICAL YEAR	DRY YEAR	NORMAL YEAR	WET YEAR	WEIGHTED AVERAGE	
19	INITIAL TOTAL NUMBER OF SPAWNERS	5000	5000	5000	5000	5000	
	HATCHERY						
20	NUMBER OF SPAWNERS ENTERING HATCHERY	1150	1150	1150	1150	1150	
21	EGGS FROM FISH RETURNING TO HATCHERY	1851500	1851500	1851500	1851500	1851500	
22	TOTAL HATCHERY EGGS NEEDED	5833000	5833000	5833000	5833000	5833000	
23	EGGS OR FRY IMPORTED FROM OTHER HATCHERY	3981500	3981500	3981500	3981500	3981500	
24	NUMBER OF SMOLTS RELEASED AT MRFH	0	0	0	0	0	
25	NUMBER OF SMOLTS RELEASED IN DELTA	0	0	0	0	0	
26	NUMBER OF YEARLINGS RELEASED AT MRFH	0	0	0	0	0	
27	NUMBER OF YEARLINGS RELEASED IN DELTA	3499800	3499800	3499800	3499800	3499800	
	RIVER						
28	NUMBER SPAWNING NATURALLY IN RIVER	3850	3850	3850	3850	3850	
29	EGGS DEPOSITED IN RIVER	6198500	6198500	6198500	6198500	6198500	
30	FRY HATCHING IN RIVER	1549625	1549625	1549625	1549625	1549625	
31	NATURAL SMOLTS ENTERING LAKE LODI	1006946	1006946	1006946	1006946	1006946	
32	TOTAL SMOLTS ENTERING LAKE LODI	1006946	1006946	1006946	1006946	1006946	
33	SMOLTS SURVIVING LAKE LODI	322223	292014	281945	281945	291813	
34	NUMBER OF SMOLTS TRAPPED AND TRUCKED	322223	292014	281945	281945	291813	
35	SMOLTS MIGRATING NATURALLY TO DELTA	0	0	0	0	0	
36	NATURALLY PRODUCED SMOLTS TO DELTA	0	0	0	0	0	
37	SMOLTS MIGRATING NATURALLY TO CHIPPS ISLAND	0	0	0	0	0	
38	SMOLTS TRUCKED TO CHIPPS ISLAND	257778	233612	225556	225556	233450	
39	TOTAL SMOLTS TO CHIPPS ISLAND	257778	233612	225556	225556	233450	
40	YEARLINGS TO CHIPPS ISLAND	3149820	3149820	3149820	3149820	3149820	
41	NUMBER SURVIVING TO BE HARVESTED OR SPAWN	196723	195998	195756	195756	195993	
42	NUMBER HARVESTED	129837	129358	129199	129199	129355	
43	TOTAL NUMBER LEFT TO SPAWN	66886	66639	66557	66557	66638	
44	NUMBER STRAYING TO OTHER RIVERS	63541	63307	63229	63229	63306	
45	NUMBER RETURNING TO MOKELUMNE	3344	3332	3328	3328	3332	
	NATURAL SMOLTS RETURNING	0	0	0	0	0	0%
	TRUCKED SMOLTS RETURNING	131	119	115	115	119	4%
	RIVER YEARLINGS RETURNING	0	0	0	0	0	0%
	DELTA YEARLINGS RETURNING	3213	3213	3213	3213	3213	96%
		3344	3332	3328	3328	3332	

conform with the two production alternatives by producing the equivalent of 3.8 million combined smolts and yearlings. Under this alternative, however, all fish would be released as yearlings. All hatchery production would be reared to yearling size and trucked to the Delta for release in the fall, maximizing returns to the ocean fishery.

Conditions would be good for spawning and rearing between Camanche Dam and Lake Lodi. All natural production would be trapped above Lake Lodi and trucked below the Delta for release in all years to avoid Delta mortalities. The only variation in natural smolt production in different year types would be caused by passage through Lake Lodi. No flow would be provided below Woodbridge for salmon or steelhead except during the salmon in-migration period.

Natural production would yield 220,000 to 250,000 smolts to be trucked to Chipps Island and hatchery releases of yearlings would account for about 3 million at Chipps Island. About 195,000 of these fish would either be harvested or return to spawn. Of these, 130,000 would be harvested, while about 67,000 would be left to spawn. At assumed straying rates of 95 percent, about 3,300 of these should return to the Mokelumne.

Under this alternative, the harvest would be nearly double that of the next highest alternative (production/hatchery alternative). The majority of production would be yearlings released in the Delta (Table 4.22). Natural production would account for only about 5 percent of total production, and all natural production would be trapped and trucked to the Delta for release.

The life cycle model predicts an average return of about 3,300 salmon from an initial average run of 5,000, which indicates a declining population. This alternative would not rely on a sustained run in the Mokelumne but is intended to support high levels of ocean harvest through hatchery production. This alternative would not address the CDFG objective of increasing salmon and steelhead runs by emphasizing natural production over hatchery production. This alternative relies heavily on releasing yearlings in the Delta to support harvest and, therefore, should be considered experimental. There is no precedent for yearling releases of this magnitude out of the Mokelumne.

4.4.7 Summary

In this summary, the management alternatives are compared and two are selected for additional investigation. We predicted and compared chinook salmon production, harvest, and escapement under each of the other management alternatives in Table 4.22. One alternative carried forward for purposes of analysis and comparison, is the CDFG Plan (4.3.3).

Only two of the other alternatives (production/natural and production/hatchery) would result in returns to the Mokelumne that equal or exceed the initial number of spawners. The other alternatives require some level of external support (import of eggs and fry from other systems or attraction of stray spawners into the Mokelumne) to maintain a stable production. On this basis, we excluded the escapement-oriented and maximum harvest alternatives from further consideration and were able to compare the two production-oriented alternatives for a final selection. Both of these alternatives and the CDFG Plan rely heavily on the release of yearling salmon to obtain high returns of spawners.

The differences between the two alternatives (production/natural and production/hatchery) are related to hatchery production levels and release strategies, primarily differences in hatchery production. The production/natural alternative emphasizes creation of natural stock and self-sustaining runs of anadromous fish. This is consistent with EBMUD and CDFG regulations, positions, and policies. The number of smolts migrating naturally through the Delta under the natural alternative is about 2.5 times of that under the hatchery alternative. Also, the natural alternative would improve habitat conditions for many other fish species that use the river.

Therefore, the production/natural alternative is selected for further comparison to the CDFG Plan. This alternative is developed, described, and evaluated in greater detail in Section 5.0.